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CORK TREE

A SPECIES of oak which grows from 30 to 40 feet in height, and has a remarkable development of soft, cellular tissue in its bark, known and utilized as cork. The bark is taken from trees generally after their twentieth year, and is removed every eight or ten years—an operation, which, curiously enough, instead of blighting the tree, promotes a hardier and more vigorous growth, and leads to the production of cork of a finer and closer texture.

DATE

A PALM-TREE known as *phœnix dactylifera.* It is the palm of biblical and classical reference. It is native to Asia Minor, India, and Africa. It has been an important plant in human economy for ages. The trees consist of a straight stem of nearly uniform diameter standing from 25 to 60 feet high. The trees are diœcious, some of the trees bearing flowers with stamens only and others, those with pistils only. Those with pistillate flowers alone bear fruit. The fruit appears at the top of the tree in bunches of from 150 to 250 dates, and weighing from 20 to 25 pounds. The tree begins to bear fruit when eight years old; is mature at 25, but lives to be over a hundred years old. The fruit is a staple among the Arabs, being eaten both raw and preserved. Cakes are made from it. The stones when ground form a substitute for coffee and are also fed to the camels. Baskets and bags are made from the leaves; and a strong rope from the bark fibers near the root. The date palm ranks next to the cocoanut palm in usefulness.

EBONY

THIS is the black heart-wood of several species of trees in tropical countries. It is extremely hard and takes a high polish. It is much used in cabinet and in inlaid work. The best comes from Ceylon from a species of *Diospyros.* The East Indies, the Coromandel Coast of India, Jamaica, British and French Guiana, supply large quantities. That of the West is usually not quite black, but presents shades of brown and green.

ELDER

THE species of shrub known as *Sambucus.* It is found both in Europe and America. It bears black or red berries. The stems contain a very large pith. The flower is usually white and very small. A wine is made from the berries. The wood is yellow and

will take a high polish. It is used for making mathematical instruments, weavers' shuttles and shoe-pegs. The pith is used in electric experiments on account of its extreme lightness.

EUCALYPTUS

A GENUS of trees mostly native to Australia. They grow to great size, sometimes 8–16 feet in diameter; and a plank 148 feet long was shown at the exhibition at Crystal Palace, London, in 1851. They yield an essential oil called eucalyptol, which is used for an antiseptic dressing.

FIG

A GENUS of trees of the order *Moraceæ*. There are more than 100 species, some of which are very large trees. They are very abundant in the Himalayas and throughout India. The fruit is an important article of food in the East and is of a certain medicinal value. The best come from Smyrna. Through recent investigations of the entomological department of the U. S. an insect has been found that fertilizes the female flowers on the trees in California and the yield has during the years 1900 and 1901 been so largely increased that foreign importation will in a few years be shut out.

HEMLOCK

A GENUS of plants which belong to the order *Umbelliferæ*. The common roadside hemlock (*Conium maculatum*) has a root resembling a parsnip; the stem is from 2 to 7 feet high, usually purple-spotted, and the leaves are large of a dark shining green color. The plant is poisonous. The Greeks compelled criminals to drink a decoction made from the plant, and it was thus Socrates died.

LABURNUM

A SMALL leguminous tree, *Cytisus Laburnum*, a native of the Alps, and neighboring mountains. Cultivated for the beauty of its pendulous racemes of yellow pea-shaped flowers. Also called golden-chain and bean trefoil.

LEMON

THE fruit of the *Citrus medicus* is a tropical fruit, and belongs to the Orange family. The tree is about twelve feet high, very knotty, and a single tree has been known to produce 3000 lemons in a season. The well-known fruit is the source of citric acid, to which

the acid taste is due. The oil and the essence of lemon are obtained from the rind by pressure. The tree grows wild in India, but is now extensively cultivated, especially in Italy, Spain, Portugal and Florida. The flowers are purplish and have a fainter odor than those of the Orange.

The Citron belongs to the same species. The tree grows to the height of from 5 to 15 feet and bears large oval-pear-shaped leaves. The fruit differs from the lemon in having a thicker rind and no umbo or projection at the end.

The Lime is of the same species. The fruit is much smaller and yields a juice known as lime-juice which is useful as a preventive of scurvy which is so liable to attack those who live on salt-meat. The juice forms a needed adjunct to Arctic expeditions.

LIGNUM VITÆ

THE wood of *Guaiacum Officinale*, grown extensively in the West Indies. It is remarkably hard and tough, and is used for manufacturing and medicinal purposes.

LILAC

A GENUS of plants belonging to the order *Oleaceæ;* a native of Persia, and was first brought to Europe by Busbecq. It is one of the commonest ornamental shrubs cultivated in Europe and America.

LOGWOOD

THE dark-red solid heartwood of *Hæmatoxylon Campechianum.* It grows extensively in Mexico and Central America and was in the 18th century introduced into Jamaica. It has a slight odor, resembling that of violets, a sweetish taste, and is astringent. Its extract is much used as a red dye.

MANGO

A GENUS of trees, native to India, which produces a smooth kidney-shaped fruit, in some cases as large as an orange, of a luscious, sweet, or slightly acid, taste. The fruit is a favorite dessert.

MANGROVE

THE Mangrove or *Rhizophora* possesses the remarkable peculiarity of sending down aërial roots from the lower part of the stems and they take root in the shore-mud of the streams near which the plants grow. The seed sprouts in the fruit while attached to the

tree and these growing plants extend downwards and take root. In this way an impenetrable thicket is formed which often extends for miles along the streams and shores. The plant resembles the banyan-tree in its mode of growth. It is found in both hemispheres. The wood is hard, lasting, and dark red. It is used in building and is susceptible of a high polish.

MANNA

Several species of Ash, especially the Manna-Ash or *Fraxinus Ornus*, in Sicily, Italy, and other places in the south of Europe yield a sweetish substance when incisions are made in the stem. This is called manna. It is mainly sugar, mucilage, resin, and gum. It is used in medicine as a mild laxative, especially for children and the aged. Other trees such as the Eucalyptus, the Tamarisk of Persia and Arabia yield a pleasant-tasting product. It was with this substance that the children of Israel were fed in their wanderings as related in Exodus and Numbers.

MULBERRY

A genus of the order *Moraceæ*, native of temperate and warm climates. The fruit is oblong, sweetish, but insipid. The silkworm feeds upon the leaves, especially reared for this purpose in the north of Italy.

MYRTLE

A genus of *Myrtaceæ;* native of all the countries around the Mediterranean Sea and of the temperate parts of Asia.

NUTMEG

In the West Indies, and in British Guiana, the nutmeg is produced in large quantities. The nutmeg tree grows from twenty to thirty feet high, and bears during a period of seventy or eighty years. It has the appearance of a pear tree. Its smooth bark is gray in tone and its trunk abounds in yellow sap. Its oblong leaf is from five to six inches in length, terminating in a sharp apex; the upper surface is dark green and the under part a shining white. Some centuries ago the nutmeg was grown on ten islands of the Banda group. In later years, however, the production was restricted, by the Dutch who owned the islands, to four islands.

The fruit of the nutmeg tree is pear-shaped and about the size of a peach. At maturity, it opens into halves. The interior contains the seed and its appendages, and the outer portion has a thick covering of a brown color. The maximum product of the tree is attained, from seed, in fifteen years. There are three periods of harvesting: during July and August, when the fruit is more abundant; in November, when the nuts are smaller; and during March and early April. In the last-mentioned season the product is dry, and not abundant. Five pounds of nutmegs are frequently gathered in a single picking from one tree. The fruit is gathered by means of a barb at the end of a long pole. The outer husk is then removed, and the mace is carefully separated by the aid of a knife. The drying of the product is accomplished by exposure to the sun's rays or by artificial heat. Salt water is sprayed over the nutmegs as soon as the golden-brown color makes its appearance; the application of water is a curing process which aids in their preservation. Drying nutmegs by artificial heat, which is done in wet weather, is effected by placing them over a slow fire, in a heat of one hundred and forty degrees. About two months afterward the nut has shrunk and rattles freely in the shell, which is then broken with a mallet or by machinery. The nutmeg proper then appears; it is olive-shaped, one inch long, and has distinctly marked furrows. Nuts which have previously been dipped in milk of lime show traces of white in these furrows.

OLIVE

The Olive, Oil-tree, or *Olea Europæa*, is a tree of great antiquity. It grows to a height of about forty feet and terminates in a rounded top. The branches and trunk grow in gnarled and fantastic shapes. The leaves are small, lance-shaped, dull green above and silvery below. It is an evergreen and does well even on very poor soil. The cultivated variety is *Olea sativa.* The Wild Olive or *Olea Oleaster* is worthless. The fruit is the most valuable part of the tree and is a drupe or berry with a stone seed. It is bluish-black when ripe. The fruit for pickling is gathered when green, soaked in potash and lime solution to extract the bitterness and then bottled in a saline solution. The pulp of the fruit abounds in a fixed oil, called olive-oil. It is rather tasteless, yellowish, and inodorous. It is a non-drying oil and the lightest of all fixed oils. It is used in cooking and as a salad-dressing. It enters into the composition of ointments, liniments, and plasters. It is also a lubricant, an illuminating oil, and an ingredient of soap. The fruit which is just ripe enough to fall produces the best quality; and that which is pressed

out without the aid of heat or water, the virgin oil, is the very best. The second pressing gives a little inferior quality and when water and heat are applied, pyrene oil of a poorer grade is obtained. The best quality and the greatest quantity of olive-oil comes from Italy. Olive-oil is much adulterated with cottonseed oil, and other substances. It is also called sweet-oil. The Olive-tree was considered sacred to Pallas Athene or Minerva. Olive-wreaths were placed upon the heads of victors; and the olive-branch is regarded, by some, as an emblem of peace.

PALMS

The Palms or *Palmæ* form an order of useful plants second only to the grasses. They rise sometimes to a height of from 150 to 190 feet. The stems are of almost uniform diameter and bear no leaves except near the top. These leaves are, in some varieties, enormously large. Some have measured 30 feet in length and 8 feet wide. It is estimated that the species number over 1,100. They are most abundant in tropical regions, especially of America. The growing bud at the end of the stem is edible, especially in the cabbage-palm. The fruit of many palms forms an article of food, as the cocoanut, date, etc. The Sugar Palm yields a sugar, the Wax-Palm a wax. The Sago Palm which grows in New Guiana and in the Indian Archipelago yields sago. The Ivory-Palm, a species of Phytolephas, grows in South America and produces a group of from 4 to 9 seeds in a head weighing about 25 pounds. The seed is as large as a hen's egg and resembles ivory very closely in color and in texture. It is known as vegetable ivory and is carved in ornamental designs. Many palms yield a juice or sap that is manufactured into fermented liquors. Palm-oil is an important product of the seeds of some species.

PEPPER

A genus of plants of the natural order *Piperaceæ*, consisting of plants with woody stems, covered with flowers on all sides, and solitary spikes opposite the leaves. The flowers are hermaphrodite. It is a native of the East Indies, but is cultivated extensively in many tropical countries.

POMEGRANATE

A fruit native to the warmer temperate parts of Asia and Africa. It is as large as an orange with a thick leathery rind of a fine golden yellow.

QUASSIA

THE Quassia is a tree of two species, one from tropical Africa; the other from tropical America. The latter, the *Quassia Amara*, is best known. It originated in Surinam, and is said to take its name from that of a slave who first used the extract of the wood in treating fevers. It appears in the drug stores in the form of chip; sometimes as wooden cups. Water poured into the cup and allowed to stand over night partakes of the intensely bitter taste of the wood and is drunk as a tonic bitter.

QUINCE

THE Quince, or *Pyrus*, is a member of the Rose family and is a common fruit used as a preserve. It is pear-shaped, yellow and very hard, but becomes soft on boiling. It is usually preserved with apples. The seeds yield a mucilaginous juice used in eye-lotions and demulcents. It also furnishes the mucilage used in marbling books. The tree is small, seldom over 20 feet in height and bears solitary flowers at the ends of the branches.

SANDALWOOD

THE Sandalwood, *Santalum*, presents a variety of shrubs and trees, bearing flowers without petals, and furnishing a hard close-grained heart-wood of a yellow or brown color. A valuable oil is obtained from the heart and the root. This oil is much used in perfumery and in medicine. From the wood, chests or boxes are made for ornamental and useful purposes. The wood is burned as incense in the worship of the Chinese. It is a native of Australia and southern Asia. The Red Sandalwood is obtained from an East Indian species of *Pterocarpus*, and furnishes a useful woolen dye. There is also a Yellow Sandalwood of the West Indies and a Venezuelan Sandalwood.

SENNA

SENNA is the dried leaflets of many varieties of Cassia. The better qualities come from Alexandria and India. The leaves are steeped and used as a mild, safe, and effective purgative. The plant has pinnately compound leaves, and the seeds are formed in large flattened pods.

SHADDOCK

Shaddock or Grape-fruit is the name applied to the fruit of the *Citrus decumana*, a variety of the Orange genus. It is a native of the Malay and Polynesian lands, but is grown in Florida. The tree is about 35 feet high. The fruit is much like an orange in appearance except that it grows sometimes to a weight of many pounds. It is divided into many portions by tough, bitter partitions. Its taste is pleasant and it is a wholesome article of food.

TAMARIND

The Tamarind is a tree of tropical growth. It is often 60 or 80 feet high and has dense foliage. The fruit is borne in pods 3 or 6 inches long, and contains a pleasant, acid juice from which a grateful cooling drink is made, which is much enjoyed by fever patients. It is preserved for export and is recognized as an officinal preparation by pharmacists.

TEAK

Teak, or *Tectona*, is a magnificent timber-tree of southern Asia and Malay. It grows to a height of from 120 to 150 feet and often girths 25 feet. It supplies a yellowish or brownish wood, straight-grained, easily-worked, and not liable to crack or warp. It is much used in ship-building, in the finishing of cabins. Its durability is due to an oil used as linseed-oil and in varnishes. The leaves droop and are from 10 to 12 inches broad. A red dye is obtained from them.

TREE, LARGEST IN THE WORLD

In San Francisco, encircled by a circus tent of ample dimensions, is a section of the largest tree in the world—exceeding the diameter of the famous tree of Calaveras by five feet. This monster of the vegetable kingdom was discovered in 1874, on Tule River, Tulare County, about seventy-five miles from Visalia. At some remote period its top had been broken off by the elements, or some unknown forces, yet when it was discovered it had an elevation of 240 feet. The trunk of the tree was 111 feet in circumference, with a diameter of 35 feet 4 inches. The section on exhibition is hollowed out, leaving about a foot of bark and several inches of the wood. The interior is

100 feet in circumference and 30 feet in diameter, and it has a seating capacity of about 200. It was cut off from the tree about 12 feet above the base, and required the labor of four men for nine days to chop it down. In the center of the tree, and extending through its whole length, was a rotten core about two feet in diameter, partially filled with a soggy, decayed vegetation that had fallen into it from the top. In the center of this cavity was found the trunk of a little tree of the same species, having perfect bark on it, and showing regular growth. It was of uniform diameter, an inch and a half all the way; and when the tree fell and split open, this curious stem was traced for nearly 100 feet. The rings in this monarch of the forest show its age to have been 4,840 years.

TREE THAT BEARS THE LARGEST LEAVES, THE

The palm family bears larger leaves than any other tree. The Inaja palm, growing on the banks of the Amazon, has leaves which reach from 30 ft. to 50 ft. in length and 10 ft. to 12 ft. in breadth. Specimens of the leaves of the talipot palm, a native of Ceylon, have been met with 20 ft. long and 18 ft. broad. These leaves are used by the natives to make tents, and, thus employed, they make very efficient shelters from rain. The leaves of the double cocoanut palm are often 30 ft. long and several wide. The leaves of the cannibal tree of Australia resemble broad planks, and are frequently 15 ft. long, 20 in. broad, and 1½ ft. thick at the base. These board-like leaves all shoot out at the top, and hang down so as to form a sort of umbrella around the stem. The umbrella tree of Ceylon has leaves of such enormous size that a single one will cover from fifteen to twenty men, and often serves as a canopy to a boat, or a tent for soldiers. A specimen leaf brought to England measured 36 ft. round. Another large-leaved plant is the *Victoria Regia*. One of the specimens of this magnificent water-lily in the gardens of the Royal Botanic Society, in England, had a leaf 7 ft. in diameter, and capable of supporting a weight of 400 lb.

UMBRELLA TREE

The popular name of a species of the Magnolia, suggested by the size and the peculiar growth of the leaves upon the ends of their stems. The tree flourishes in the Alleghany region.

WILD FLOWERS

TRAILING ARBUTUS

Heath Family.

One of the earliest flowers you will see in the spring, if you live in New England, or in any other northern part of America, is the Trailing Arbutus, or, as it is more commonly called, the Mayflower. The poet Whittier has written a lovely poem about this flower, in which he connects it with the Puritan ship "Mayflower," from which the pilgrims landed at Plymouth, in 1620. We all ought to read that poem, and if we know the Mayflower, and have gone into the woods and gathered it, we will read with much keener pleasure what the poet has so beautifully said.

Every wild flower, no matter how small or unimportant looking it may be, has been given a Latin name. These names are sometimes very long — in fact, almost as large as the flowers themselves, — and you may wonder, for instance, why this plant cannot be called the Mayflower, which is a much prettier name than the one the botanists use — *Epigæa repens.* The reason is that by the use of Latin words men and women of all nations have one name by which the flower is known the world over, so that a botanist has only one name to learn, instead of learning one in each language. The name *Epigæa repens* means "creeping on the ground," which is a very good name for the plant, for that is just what it does.

You will find this flower in April and May, just after the snow has melted. Its leaves are rounded, and the base is indented so that it is heart-shaped. If you feel them you will find that they are quite thick and hard. The stem is covered with rusty, brown hairs. You will be surprised to see the plant have so many leaves so early in the spring, but you must remember that it is evergreen.

The blossoms are generally pink, some being a much deeper shade than others, and a few are white. They grow in clusters, and are very fragrant, which helps to make the Mayflower a welcome visitor. The blossoms look quite waxy, and if you examine them closely you will see that the colored portion, which is called the *corolla*, is made up of five parts. When you look into the tube you will see a number of hairs, and you can count ten match-like bodies that are called

stamens, while in the center is a single upright part called the *pistil.* This is different from the stamens, and is a very important portion of the flower, since it and the stamens are chiefly concerned in producing the seeds.

Around the outside of the corolla is a greenish portion, called the *calyx*, which is composed of five leaf-like little parts, each of which is called a *sepal.* Now every single part of a plant or flower has its uses, and one of the most interesting things about the study of plants is to find out what each part is for, and to see how wonderfully each organ is fitted for the work it has to do.

The chief use of the *calyx*, and the *corolla*, is in the protection of the bud, for you will notice that when the flower is in the bud it is all rolled up so as to protect the delicate parts within from injury. The *stamens* and the *pistil* reproduce the plant by forming the seed, and they do this in a very interesting way. If you look closely at one of the *stamens*, you will see that it consists of two parts: one of them, called the *filament*, is long and thread-like, and supports the other, which is a larger body, called the *anther*. If you open this *anther* you will see a yellowish dust fall out. This dust is called the *pollen*, and it, too, plays a very important part in the formation of the seed.

The central organ of the flower is the *pistil*, which is made up of three parts; the lowest of these, called the *ovary*, is the part in which the little seeds form; the second is the *style*, and its use is simply to support the third, called the *stigma*. This *stigma* is covered by a sticky juice, which holds the pollen grains when they fall from the *anther* upon the *stigma.*

Dalmatian powder, which is sold for sprinkling about the house to kill flies, is the pollen of a plant that is grown in Dalmatia, on the shores of the Adriatic Sea. When you think of the immense quantities that are used, and then of the small size of the *anthers* in which it is formed, you can form some idea of the number of plants that must be grown for its production.

You may have noticed in early spring a quantity of yellow dust sprinkled over the surface of a brook or pond, where there is an overhanging tree. This is pollen that the wind has carried there. If you can see the grains of this powder under a magnifying glass, you will notice that each is a little ball. It is more like a football than any other kind, for each grain has two coats, an outer one that has a few weak spots in it, and an inner one that is quite elastic. Inside of all is a peculiar matter that is almost liquid.

When the pollen falls on the sticky juice of the *stigma*, the grains absorb enough of this liquid to make them swell, and the inner coat

bursts out through one of the weak spots in the outer one and forms a tube. This tube finds its way down through the cells in the *stigma* and *style*, and the liquid contents of the pollen grain passes down into the *ovary*, and changes the little bodies it holds into seeds.

Does it not seem wonderful indeed that the tube of the pollen grain should be able to find its way, sometimes as far as one or two inches, down through the other parts to the *ovary?* This is only one of the many really wonderful things that are hourly going on in Nature, of which we take little notice; but the study of Nature brings them to light, and well repays us for our interest. So try to find the parts named, in the first flower you see, and next spring, after the snow has gone away, go out into the woods, especially among the pines and push aside the dead brown leaves of last year, and you will see what the poet meant when he said:—

> "But warmer suns ere long shall bring
> To life the frozen sod,
> And through dead leaves of hope shall spring
> Afresh the flowers of God."

SHEEP=LAUREL—LAMBKILL

Heath Family

This plant is not so large as the Mountain Laurel, attaining a height of only three feet. Its flowers, too, are smaller; but they are exceedingly pretty, with their delicate crimson-pink color. As in the Mountain Laurel, the stamens are bent over and caught in depressions of the five-lobed corolla; the calyx is five-parted. There are ten stamens and one pistil. This flower is the most poisonous of the genus. It is fatal to sheep, but deer are said to feed on it without danger.

MOUNTAIN=LAUREL—SPOON=WOOD—CALICO=BUSH

Heath Family

This plant is one of the glories of nature, and is found not only in the mountains, but in the lowlands as well. It probably assumes its greatest height in the mountains of Pennsylvania. To see it growing there in its wild luxuriance, is a sight never to be forgotten. Sometimes a whole mountain side is flushed with it; one might imagine that the roseate clouds of the summer skies had become entangled among the trees.

It is an evergreen shrub, with glossy, oblong, pointed leaves of a leathery texture. The buds are pink, and the full flowers are pure white, or pink-white. They have a five-pointed calyx, and a peculiar wheel-shaped corolla, with five lobes and ten depressions. There are ten stamens and one pistil. It is the stamens that produce the wheel effect; each is bent over and fastened in a depression of the corolla. Nature did this for a good reason; whenever a bee touches one of the stamens, the slender filament springs back, throwing pollen dust over the bee. The dusty insect then carries the pollen to another flower. This is not the kind of Laurel with which the Ancients crowned their brows, although it is similar.

A sticky substance exudes upon the blossoms and flower stalk. This is to hold fast the smaller insects that might loosen the stamens and scatter the pollen, without being able to carry it to another flower. It is one of the wonderful ways in which plants protect themselves.

The Laurel leaves are said to be poisonous, and there is a tradition that the Indians used them for committing suicide. The scientific name of the plant is Kalmia, and was given to it by the great botanist, Linnæus, because a man by the name of Peter Kalm first told him about the American Laurel. It is called Spoon-wood, because the Indians made eating utensils from its wood. It is sometimes called Calico-bush, because it bears a certain resemblance to that cheap, printed material.

AMERICAN RHODODENDRON, OR GREAT LAUREL

Heath Family

THE luxuriant beauty of this shrub rivals the Mountain Laurel. It grows in the eastern states, and is found more abundantly in the Alleghany Mountains than elsewhere. It is from six to thirty-five feet high, has thick, leathery, oblong leaves, and the clustered flowers are white or pale rose, about one inch broad; they have a very small, five-clefted calyx, ten stamens, and one pistil. The five-parted corolla is somewhat bell-shaped, with a greenish throat, and the upper part is marked with yellow or reddish spots.

As in the Laurel, a sticky fluid exudes from the flower stalk, in order to protect the blossoms from the assaults of the little, useless insects. One of the greatest rewards of a mountain climb in June is to find the Rhododendron; it springs like a glory from the most inaccessible spots of the twilight woods. Sometimes we find it hanging over the edge of a great cliff, like a flurry of sun-flushed snow.

Indeed, some districts of the mountains are so overgrown with its interlacing branches as to make the woods well-nigh impassable. These jungles are called "Hells," by the mountaineers.

The nectar of the flower is said to be poisonous. Xenophon, the renowned Greek historian, relates that, during the return of his ten thousand troops, they found and ate some honey that the bees made from this nectar, and became very ill in consequence. The leaves retain their green color all winter. In some of our public gardens the plant is cultivated, and under these conditions the flower attains a width of one and a half inches.

SQUAW HUCKLEBERRY

Heath Family

This plant grows to a height of two or three feet, its stems are profusely branched and the flowers are greenish white or purplish, reminding one of the Blueberry or the Huckleberry. The pear-shaped berry is hardly good to eat, but the fragrant flowers are very pretty and the leaves have a dainty effect, being pale green above, with a whitish under surface.

LABRADOR TEA

Heath Family

This shrub grows from two to three feet high. It is found throughout Pennsylvania, but flourishes most freely in the mountains and swamps in the southern and eastern portions of that state. It is easily recognized by the woolly under surface of its leaf.

The small, white flowers cluster at the end of the stem; they have a five-petaled corolla, and a small, five-toothed calyx. There are from five to ten stamens and one pistil.

PIPSISSEWA OR PRINCE'S PINE

Heath Family

This fragrant flower ornaments the woods during the latter part of June and in July. It grows in sandy soil, amid decaying leaves, and is one of the last blooming of those dainty flowers which make the springtime woods so beautiful, and which are crowded out, as the season advances, by hardier flowers; consequently, as we observe the frosty pink flower and inhale its delicious fragrance, our pleasure is mingled with regret.

The stem is from four to ten inches high, the glossy leaves are olive green, and somewhat lance shaped, with sharply-toothed edges; they retain their color all winter. The flowers grow in a loose cluster at the end of the stem; they have a corolla of five, rounded spreading petals, and a five-lobed calyx. There are ten stamens, and one pistil. In the White Mountains there is a variety of this plant with white-spotted leaves.

THE SHIN=LEAF

Heath Family

This is a beautiful plant with an ugly name. It is so called because our forefathers used its leaves for healing bruises and cuts, and a leaf, or plaster, for healing bruises, no matter on what part of the body, was called a Shinplaster. Its Latin name is *Pyrola elliptica.* Salmon, the herbist, says the Romans called it *Pyrola*, because they thought the flowers and leaves resembled those of the pear tree.

The Shin-leaf grows in damp, shadowy, woodland dells, and is a fragrant companion of the *Pipsissewa.* It has a scaly, upright stem, and the thin, dull green, somewhat ovate, leaves are clustered around the root. At first sight the nodding white flowers remind us of the Lily of the Valley. The corolla is divided into five, rounded, concave petals; the calyx is five-cleft, there are ten stamens, and one pistil.

WINTERGREEN — CHECKERBERRY — MOUNTAIN=TEA

Heath Family

It is a great pleasure in the hot month of July to penetrate a shady dell, and find the Wintergreen blossoms. They look like flakes of snow, but lately fallen upon the glossy green leaves. The slender stem is from three to six inches high. The flowers grow from the axils of the leaves, and have a five-lobed calyx, and a corolla of five small teeth. There are ten stamens and one pistil.

The young leaves, having a pleasant aromatic flavor, are often used for making tea. Later in the season, the flowers give place to savory, bright red berries, that are eaten by the birds and deer. These berries hang upon the stem all winter, and the plant, with its evergreen leaves and ruddy fruit, is one of the welcome sights of an early spring ramble.

JACK-IN-THE-PULPIT—INDIAN TURNIP

This picturesque flower makes its appearance in May. The spathe, or "pulpit," in which Jack stands, is sometimes pale green, with whitish stripes; sometimes stained with purple. These purple stains give the plant its scientific name, *Arisæma*, which means *Bloody Arum*. There is a legend that says this flower was present at the Crucifixion:—

> "Beneath the cross it grew;
> And in the vase-like hollow of the leaf,
> Catching from that dread shower of agony
> A few mysterious drops, transmitted thus
> Unto the groves and hills their healing stains,
> A heritage, for storm or vernal shower
> Never to blow away."

It is called Indian Turnip, because its bulb-like base was used as food by the Indians. They first cooked it, thus destroying its sharp, stinging taste. The plant is a great favorite with children, who are delighted to find its striped pulpit, hidden by the shelter of six bright green leaves. Later in the season, a cluster of brilliant, scarlet berries appears. Jack is also a cousin of the Calla Lily, but a more acceptable one than the Skunk Cabbage.

SKUNK CABBAGE

Arum Family

This plant occupies a distinguished position, being the first to flower of the year. This fact will surprise those who have given that honor to the Trailing Arbutus, the Anemone, or the Violet. The Skunk Cabbage begins to push up from the swamps in February, and one would never imagine that it contained a flower, for it looks like a snail rising above the mud. Besides, it gives forth a disagreeable odor, that is very well in keeping with its name.

These peculiar plants are composed of a purple, mottled spathe. Within this spathe, the little flowers nestle as within a hood, and are thus protected from the cold, biting winds. Later in the season, these spathes are a favorite resort for bugs, spiders, beetles, flies and honey bees, and one can hear them buzzing, and having a merry time within. Just why they are attracted to such a malodorous place, it is hard to tell. It is especially surprising, that the honey bees can leave the beautiful scented flowers, and enter the Skunk Cabbage House.

About June, when the pistils have been dusted with pollen, the spathes wither away, and the plant puts forth clusters of bright, green leaves. It is amazing to learn that the Skunk Cabbage is a near relative of the Calla Lily. The spathe of the former corresponds with the snowy petal-like leaf of the latter. Fine plants, like fine people, sometimes have very disagreeable relations.

COMMON ST. JOHN'S=WORT

St. John's-wort Family

This plant is greatly disliked by farmers, because its rank, rapid growth impoverishes the soil. Once it gains a foothold, it is hard to extirpate. It is a much-branched plant, and reaches a height of two feet. The small, oblong leaves are opposite, and are marked with pellucid spots. The numerous yellow flowers grow in clusters, and have a calyx of five sepals, and a corolla of five bright, yellow petals, that are dotted with black. There is one pistil, and numerous stamens. Many are the superstitions that have gathered around this plant.

It is called St. John's-wort, because it was thought that the dew which formed on the flower the evening before St. John's day, would cure sore eyes. In the course of time it was accepted as a remedy for many afflictions. In early times, an ointment was made from the flowers. One of its names was "Balm of the Warrior's Wound."

COMMON MULLEIN

Figwort Family

This plant, which makes the pasture lands so picturesque, is not a native of this country, although in England it is called "American Velvet Plant." It is a native of the Isle of Thapsus. The Mullein, so familiar and common to us, played a prominent part in classical times. It was called "Candelaria" by the Romans, who dipped the long dried stems in fat, and used them for funeral torches. The Greeks utilized the dried leaves for lamp wicks. In recent times, Mullein tea is often used for pulmonary diseases. From its efficacy in curing cattle, it is often called "Bullock's Lungwort."

The Mullein is a rugged plant, growing to a height of three or five feet. The leaves are oblong and woolly, and the flowers are clustered in a long, dense spike; they have a five-parted calyx and a yellow corolla, divided into five rounded lobes. There is one pistil

and ten stamens. During the first year, the Mullein bears only its woolly rosette of leaves; not until the middle of the second summer does it bring forth its yellow flowers; but the leaves are very dainty when they first appear, being pale green, and soft as velvet.

JEWEL=WEED—TOUCH=ME=NOT

Geranium Family

This beautiful plant, of which there are two varieties, is found fringing the woodland rills, and making glad the damp, shady spots. The Pale Jewel-weed abounds in the North, and has pale yellow flowers, spotted with reddish brown. The Spotted Jewel-weed is common in the South, and has orange-yellow flowers, likewise spotted with reddish brown.

The plants grow from two to six feet high, and have alternate, coarsely-toothed, oval leaves, from the axils of which grow the nodding, loosely-clustered flowers. The calyx and corolla, being of the same color, are hard to distinguish; they are divided into six parts. Five short stamens are united over one pistil. The plant is called "Touch-me-not" because, when the seed pods are touched, they spring open with such force as to violently scatter the seeds. This is one of nature's tricks of dispersing seed. The flower is closely related to the Garden Balsam, and, although so gaudy, is scentless.

HERB ROBERT

Geranium Family

The small, purple-pink flower of the Herb Robert is found, from June till October, in woods and shaded ravines. It has a forked, hairy stem, and three divided leaves, that are again dissected. It has a five-sepaled calyx, and a five-petaled corolla, ten stamens, and one pistil. The ripened seed-pods split open, sometimes projecting the seed a distance of twenty-five feet.

The stem being ruddy, the plant, on that account, is called "Redshanks" in the Scotch highlands. A resinous secretion, such as is common with several varieties of geranium, gives it a strong odor. This secretion is sometimes so abundant that the stalks can be burned like torches.

The name Herb Robert is derived from the fact that the plant was used as a cure for "Robert's Plague," during the time of Robert, Duke of Normandy.

EVENING PRIMROSE

Evening Primrose Family

PERHAPS you have noticed during the heated summer days, a rank-growing flower by the roadside; you pass it by with a glance, for its flowers are pale and withered. If, however, you were to see it after sundown, you would give it more attention, for then the pale yellow flowers are fresh and beautiful, and give forth a delicious perfume. This is the Evening Primrose (*Onagra biennis*), which blooms at night because its flowers cannot endure the heat of the day. But notice how well it is fitted to thrive in the darkness: the flowers are fragrant and yellow, so that they can easily be detected by the pink night-moth, that carries away the pollen. On cloudy days, its blossoms are fresher looking, and, at the end of the summer, it blooms during the day, because the sun rays are not so hot.

Its stout stem averages about three feet in height, and the lance-shaped leaves are alternate. The flowers grow in a leafy spike. The calyx is a long, four-lobed tube, and the corolla is composed of four, somewhat heart-shaped petals. There are eight stamens, and one pistil.

FIREWEED—GREAT WILLOW HERB

Evening Primrose Family

THE chief peculiarity of this plant is that it grows to best advantage on burnt-over ground. Where fire has devastated the woods, the Fireweed springs up, in great abundance, as if anxious to hide the black waste with color.

Its lance-shaped leaves are scattered, and willow-like. The large purple-pink flowers grow in a long raceme at the upper part of the stem. The calyx is four-cleft, and the corolla four-parted. There are eight stamens, and one pistil. The flower gives place to a seed vessel that contains silky-tufted seeds. There is a great similarity between the blossoms of this plant and those of the Evening Primrose.

YELLOW LOOSESTRIFE

Primrose Family

During the summer, the golden stars of the Loosestrife shine in the marshes and damp woodlands. They have a dainty appearance, and are related to the little frosty star flowers that delighted us in the early spring days.

The plant ranges from one to two feet in height, and has opposite, lance-shaped leaves. The small, yellow flowers grow in a long cluster at the termination of the stem; they have a five or six-parted corolla, a five or six-cleft calyx, four or five stamens, and one pistil. There is another variety of Loosestrife, in which the leaves are whorled in groups of four, at intervals along the stem, and the flowers, instead of growing in a loose cluster at the end of the stem are scattered along its full length.

STAR=FLOWER

Primrose Family

Here is another flower, which gives us pleasure. It is somewhat similar to the Anemone, with a smooth stem and pointed leaves, whorled at the end of the stem. The flowers have a calyx of seven sepals, and a corolla of seven petals. They are star shaped, white and delicate, with one pistil, and four or five stamens. As the shafts of sunlight fall upon these starry flowers, they gleam like bits of frost against their dark green leaves.

PITCHER=PLANT—SIDE=SADDLE FLOWER—HUNTSMAN'S CUP

Pitcher-plant Family

This is one of the most remarkable of plants. Its leaves are pitcher shaped, and hold water; they are lined, near the mouth, with a sweet substance; below this there are hairs, pointing downward. Insects lured by the sweet are trapped by these hairs, and, not being able to return, are drowned. Their bodies dissolve in the water, and make a nutritious juice on which the leaves feed.

The plant is very beautiful; its broadly-hooded, winged leaves are of a rich, striped yellow, or deep-red color. The flowers are also very striking, being red, pink, or green; they have the scent of

sandal-wood. The calyx has five colored sepals, and the corolla has five petals which arch over the greenish yellow style. There are numerous stamens, and one pistil. The Pitcher Plant blooms in June, and inhabits shadowy bogs.

DOG VIOLET

Violet Family

FROM May until July this dainty little flower is found in the low, damp grounds. Its leafy stem is from three to eight inches high. The leaves are heart shaped.

TWIN-FLOWER

Honeysuckle Family

THIS is one of the most exquisite of the wild flowers. Its nodding pink petals give a flush to the cool, mossy woods of June, and its delicate fragrance is quite in harmony with its color. The stem is slender and trailing, with rounded, evergreen leaves, and the dainty flowers grow in pairs, on thread-like, flower stalks. The calyx is five-toothed, and the bell-shaped corolla is five-lobed. There are four stamens, and one pistil.

No flower has ever received a greater compliment: it was the favorite flower of Linnæus, the great botanist. There is a portrait of him that shows him wearing one of the blossoms as a *boutonnière*.

WOOD ANEMONE OR WINDFLOWER

Crowfoot Family

THIS is another exquisite flower of early spring. It has a slender stem with delicate leaflets. Its solitary flower, purple, pink or white, has a calyx of four, or seven, sepals, and has numerous stamens and pistils. One of the joys of the springtime is to walk through a wood where the Anemone grows. The flower quivers with delight beneath the breath of the gentle winds. Bryant, speaking of these flowers, said:—

> « . . . within the woods,
> Whose young and half-transparent leaves scarce cast
> A shade, gay circles of Anemones
> Dance on their stalks.»

The word Anemone means wind-flower. Pliny tells us the ancients called it by that name, because it opened at the touch of the wind. A Greek legend says that the Anemone sprang from the tears that Venus shed over the body of her beloved Adonis. Surely this flower is beautiful enough to justify such legends.

WHITE BANEBERRY

Crowfoot Family

This plant grows in the damp, shady spots of the woods, and, in May, is noticeable, on account of its feathery, white flowers. It is about two feet high, with leaves that are divided into two or three sharp-toothed leaflets. The small, white flowers are gathered in a thick bunch at the end of the stem, and have a calyx of five small sepals, that fall off when the flower opens. The corolla is composed of from four to ten flat petals. There are numerous stamens, and one pistil.

The White Baneberry becomes more attractive in the late summer; then the flowers disappear, and are replaced by a bunch of waxy, white berries. These berries are marked with purple-black spots, and are supported by a thick stem, that turns red as the berries ripen.

In penetrating the dark woods, it gives one a pleasant sensation to find this glow of color. The White Baneberry is common in the White Mountains. The Red Baneberry grows farther north, and blossoms somewhat earlier; its berries are red and grow upon a slender stalk.

MARSH MARIGOLD

Crowfoot Family

This is one of the early spring flowers, and a sight of the golden petals is like a thrill of sweet song, for we know that the ice-winds have gone, and the happy spring days have come, with their rainbow hues, and subtle fragrance. The Marsh Marigold has a hollow, furrowed stem, with rounded, somewhat kidney-shaped leaves. The golden blossoms have a calyx of from four to nine petal-like sepals, five to ten pistils and numerous stamens.

It is thought that Shakespeare referred to this flower in «Cymbeline» where he says:—

«Hark, hark! the lark at heaven's gate sings,
And Phœbus 'gins arise,
His steeds to water at those springs,
On chaliced flowers that lies;
And winking Mary-buds begin
To ope their golden eyes;
With everything that pretty is—
My lady sweet arise!
Arise, arise!»

It is very probable that the «Mary-buds» are the same as the Marsh Marigolds, because, along certain English rivers, the latter are abundant. Indeed, one observer says that when the rivers overflow their banks, the ground is so covered with these flowers, that it seems to be paved with gold.

COMMON MEADOW=SWEET

Rose Family

THE Meadow-sweet is not so common as its name might imply; in some regions it is plentiful, in others it is rather scarce. Neither is it fragrant, and this is a great disappointment, because the feathery, plume-like flowers are very pretty, with their flash of pinkish white.

We find it growing in the low meadow-lands, or fringing the river banks. It attains a height of two or three feet. The stem is nearly smooth, and the broad-toothed leaves are lance-shaped and alternate. The small flowers grow in pyramidal clusters. The corolla is composed of five rounded petals, and the calyx is five-cleft. The stamens are numerous, and there are five to eight pistils.

The name Meadow-sweet is said to be a corruption of Meadow-wort, which means «Honey-wine Herb.» Hill, in his «Herbal,» says that «the flower mixed with mead gives it the flavor of Greek wine.»

«. . . near the unfrequented wood,
By waysides searched with barren heat,
In clouded pink or softer white,
She holds the summer's generous light—
Our native meadow-sweet!»

COMMON CINQUEFOIL—FIVE=FINGER

Rose Family

During the summer, the yellow flowers of this plant enliven the woods and meadows, and fringe with brightness the country highways. The slender stem is sometimes erect, sometimes prostrate. Its leaf is divided into five leaflets, hence the name *Cinquefoil*, which is the French for "five leaves."

The flowers grow from the axils of the leaves. They have a five-cleft calyx, but between each two teeth of the calyx, there is a bract, making it appear ten-cleft. The corolla has five rounded petals; there are many stamens and pistils.

Many people mistake the Cinquefoil for a yellow-flowering strawberry; but there is much difference between the two. The leaf of the strawberry is divided into three leaflets, while that of the Cinquefoil is divided into five. Again, the stem of the former is hairy, while that of the latter is smooth. Besides, the yellow-flowering strawberry is very rare.

YELLOW AVENS

Rose Family

This is another flower that adds golden light to the damp meadow lands. Later in the season, it also adds prickly burs, that cling to our clothes as we pass. The hairy stem grows from three to five feet high, and the leaves are divided into three or five leaflets. The golden yellow flower has a five-cleft calyx, and a corolla of five broad petals. There are numerous stamens and pistils.

BLUETS—QUAKER LADIES

Madder Family

This exquisite little flower is common both North and South, but it grows in greater profusion, and reaches the climax of its beauty in the New England states. There, in the month of May, the woods are full of the dainty, modest flowers.

It has an erect stem, three to five inches high, with small, opposite leaves. The flowers are a pale, purplish blue, though they are

sometimes white, with a golden yellow eye. They have a four-lobed calyx, and corolla. The tube of the latter is long and slender. There are four stamens, and one pistil.

Some of the flowers have long stamens and a short pistil, others have a long pistil and short stamens. Because of these two forms, they are called « Dimorphous.» As a rule, in order to fertilize, the long pistils must receive pollen from the long stamens, and the short pistils must receive it from the short stamens. This flower has been successfully cultivated in gardens.

PARTRIDGE=VINE

Madder Family

THIS is another plant whose evergreen leaves and brilliant berries give us a thrill of pleasure, when the snow disappears. As we come upon it in some sheltered, hillside nook, we cannot help wondering how the mass of dainty leaves could withstand the cold winter.

It does not bloom until June; then the little twin, funnel-shaped flowers intoxicate the senses with their exquisite perfume. They are pink-tipped. The corolla is divided into four spreading lobes, and the calyx is four-toothed. There are four stamens and one pistil, and the ovary of each flower is united to that of its sister flower.

The stem is smooth and trailing, and the rounded leaves are veined with white. The bright scarlet berries, like the flowers, are double. The Partridge-vine is found in Mexico and Japan, as well as in America.

SKULL=CAP

Mint Family

DURING July and August, the Skull-cap is found lifting its blue plumes in the tall grass of the meadows and waysides. There are three varieties, of which the *Scutellaria integrifolia* is the most attractive. Its flowers are about one inch long, and grow in terminal racemes. They have a two-lipped calyx, the upper lip having a helmet-like appearance, from which the plant derives its name. The corolla is also two-lipped, the upper lip being arched, and connected with the side lobes; the lower lip is spreading, and notched at the point. There is one pistil, and four stamens in pairs.

The best-known variety is the « Mad-dog Skull-cap,» (*S. lateriflora*). It was once thought to be a sure cure for hydrophobia. It abounds

in wet places, and its flowers grow in one-sided racemes. The *S galericulata* is found in the North. Its flowers which grow from the axils of the upper leaves, are smaller than the *S. integrifolia* and larger than the *S. lateriflora.*

SELF-HEAL—HEAL-ALL

Mint Family

FROM June to October, all over the land, this little blue-purple flower decks the roadsides and the pastures. It has a low stem, with opposite oblong leaves, and the flowers grow in a spike. The calyx is two-lipped, the upper lip having three teeth, while the lower one has two clefts. The corolla is also two-lipped, the upper one arched, the lower one with three clefts. There are four stamens, and one pistil.

This plant is not only common, but it is also valuable as a medicine. The Germans thought it a sure cure for quinsy. Indeed, the scientific name of the plant, Brunella, is a corruption of the German word Prunella, which means quinsy. In England, it was often applied to the wounds of laborers. The French also knew the virtue of the flower, and this is one of their proverbs, "No one wants a surgeon, who keeps Prunella." Its honey is a great favorite with the bees, and so long as the Prunella blooms, a bee is almost always to be found with his head buried in the succulent corolla.

PURPLE FRINGED ORCHIS

Orchis Family

NATURE sometimes adorns the hidden swamp with her rarest gems. We have seen that she places the gorgeous Pitcher Plant there, and here is another beautiful flower that blooms unseen, save by a few eyes. In July we find the Purple Fringed Orchis making glad the wet places.

There are two varieties, the *Habenaria fimbriata*, and the *Habenaria psycodes.* The former has oblong or oval leaves, the upper ones are few, and pass into lance-shaped tracts. The large flowers grow in a spike and have a long, curving, fan-shaped, three-parted lip; the divisions are fringed.

The latter variety has lance-shaped leaves, the upper ones passing into a linear bract. The fragrant, purple flowers resemble the *H. fimbriata*, but are much smaller, and have a less fringed lip. They also grow in a spike. The Purple Fringed Orchis attracted the admiration of Thoreau, the eccentric New England nature lover.

THE LADY'S-SLIPPER

Orchis Family

You will find the beautiful wild Lady's-slipper blooming in the latter part of May, and you cannot mistake it, for its peculiarly shaped blossom is sure evidence. The Indians called it the "Moccasin Flower," and in the French it is "The Virgin's Sabot," or slipper. Our English forefathers called it "Our Lady's Slipper," which came to be the common name for the flower. One sort is yellow, and another is rosy purple, mingled with white. Both are so showy and lovely that the lucky finder can hardly resist the temptation to pluck them, and thus they grow rarer every year.

The Lady's-slipper belongs to the Orchids, that royal family which the botanists tell us is the most highly organized of all plants. It is a large family and widely distributed in both hemispheres. The Lady's slipper is generally a single flower, which hangs from a long, leafy stem. It has three sepals, of which the upper is the largest. The formation and arrangement of these with the petals, the stamens and stigma, give it the resemblance to a slipper.

Its method of securing fertilization is different from that of other Orchids. There are two stamens, and the pollen is powdery, and not very different from that of ordinary flowers. The stigma is large, flat, and shaped something like a trowel, with the face turned downward. It is supported on a stout style, to which the anthers have grown fast, one on each side. This apparatus grows just within the upper part of the Slipper. You will notice three openings into the Slipper. The one in front is large and round, and the edges are turned in, after the fashion of some kinds of mouse-trap. The other two openings are small and far back, and directly under each other. Flies and like insects enter by the large opening in front, and find a little nectar bedewing the long hairs that grow from the bottom of the Slipper. The mouse-trap arrangement makes it difficult for the fly to get out by the way it came in, and as it pushes on under the stigma, it sees light beyond on either side. Thus, in escaping by either one or the other of these small openings, it is sure to get some of the pollen on its head.

Flying to the next blossom and entering as before, the fly cannot fail to rub the pollen-covered top of his head against the large stigma which forms the roof of the passage. When he passes out, he takes on his head a fresh load of pollen with which he may fertilize another flower.

The early flowering and purple stemless Lady's-slipper differs from the others in that its larger slipper has a long, narrow opening in front, instead of a round one. Although the two lips of the slit almost meet, the fly readily pushes his way in. The way of exit, however, is more open than in the other species.

LADIES' TRESSES

Orchis Family

This plant, with its slender spike of fragrant white flowers, decks the damp lowlands toward the end of summer; it is, however, sometimes found on higher ground. The lance-shaped leaves are long at the lower part of the stem, but above they are shorter and cling close to the flower-cluster, as in all orchids. The lips of the flower are wavy and crisped.

This plant is closely related to the pink and the yellow moccasin flowers. It gains its name from the peculiar way in which the flowers twine about the stem. In New England it is sometimes called « White Hyacinth.»

HAREBELL

Campanula Family

Among the wild flowers, the Harebell is second to none in delicate charm. Its dainty bright blue or purple bells, nodding on their hair-like stems, are a sight to make the heart leap with joy. The plant is exceeding fragile and ethereal looking; yet it is one of the hardiest flowers, for it survives the strongest mountain winds. It blooms from early June till late in September, and is found in the meadows as well as on the mountain cliffs.

It is identical with the rugged Bluebell of Scotland. It has a slender, branching stem, five to twelve inches high, with ovate root leaves. These, however, are not so hardy as the flowers and die early. Its numerous stem leaves are long and narrow. It has a five-cleft calyx and a bell-shaped, five-lobed corolla, five stamens, and one pistil.

FRINGED GENTIAN

Gentian Family

IN LATE September and October, the Fringed Gentian makes its appearance. One feels as though Nature had reserved her most joyous surprise for the end of the season. It was a favorite flower of Bryant, who says:—

"Thou blossom, bright with autumn dew,
And colored with the heaven's own blue,
That openest when the quiet light
Succeeds the keen and frosty night;

"Thou waitest late, and com'st alone,
When woods are bare and birds are flown,
And frosts and shortening days portend
The aged Year is near his end.

"Then doth thy sweet and quiet eye
Look through its fringes to the sky,
Blue—blue—as if that sky let fall
A flower from its cerulean wall."

One is not likely to find this flower in the same spot two successive seasons; it dies after blooming and the seeds are washed away and fall in other places.

Its stem is one to two feet high, with opposite, lance-shaped leaves. It has large, blue flowers, with a four-cleft calyx of unequal lobes, and a funnel-shaped corolla, with four fringed, spreading lobes. There are four stamens and one pistil.

The flower bells are about two inches long; they close at night and on cloudy days, but when the sun shines, they quickly open. Surely their color rivals the blue of the sky.

THE IRIS

Iris Family

MIDSUMMER in New England finds the Blue Flag, or Wild Iris, revealing its splendors on the edge of sunny waters or in low, moist fields. This is the famed lily of France, the *Fleur-de-Lis*, *Lis* being a corruption of Louis, the king who first adopted it as his badge. Its favorite haunts are concisely pictured in the first verse of a beautiful poem by Longfellow:—

"Beautiful lily, dwelling by still rivers,
Or solitary mere,
Or where the sluggish meadow brook delivers
Its waters to the weir."

The family name, Iris, is the Greek word for rainbow. It belongs to the same family as the Crocus and the Gladiolus, whose sword-shaped leaves are so placed that one seems to ride on the back of another. The species of Iris are numerous and are chiefly natives of the temperate zone. The flower of the common variety, in the British Islands, is yellow and we have some yellow varieties in this country, but our common sorts are in various shades of purple and lilac. There are three erect petals and three backward-curving sepals. The latter are adorned with a delicate tracery in dark purple and gold, the real beauties of which cannot be seen with the naked eye. The bees and marsh flies are attracted by it and carry the pollen from flower to flower. A most complex and wonderful structure enables the Iris to attract bees and larger insects, and to repel crawlers. The three spreading stigmas resemble corolla leaves, and are slightly bent backward. Under each is an anther, which is protected beneath the concave surface from the entrance of a crawler or a drop of rain.

The Iris is one of those thrifty plants which owe their splendors to the industry and economy of last year's roots. In the spring, when they begin to prepare their pretty new dresses, they are already in possession of material ready for use. Thus, they can make their appearance in dainty costumes very early, in some localities as early as March.

After the Iris has shown its rich colors for a time, it withdraws into its green sheathing again, and looks like a bud. The seeds are carried far and wide, but they perish unless they fall near the water. If you notice when a pond is made near the meadow, or the surface of the land is changed, so that there is a wet spot somewhere, it will not be many seasons before the new body of water is surrounded by the Iris and other plants that delight to keep their feet wet. The seeds of these plants were doubtless dropped into the meadow just the same when the ground was dry and unfit to nourish them. But they must have perished, as countless thousands of wandering seeds do every year.

Some varieties have been improved by the florists and are very beautiful. The Persian Iris is delightfully fragrant. Much attention is given to the production of new species in Holland, in which country much business is done in growing and exporting roots of various kinds.

BLOODROOT

Poppy Family

This is one of the most beautiful wild flowers of the year. It grows in early April, among the hillside rocks and along the borders of the woods. Its leaves are round and deeply lobed, and the flower has eight or twelve snow-white petals about a center of gold. It has one pistil and about twenty-four stamens, and the calyx is divided into two sepals.

This early visitor is apt to come and go without being seen, unless closely watched. One or two warm, sunny days bring the stem from its hiding-place, and open the exquisite flower; in a short time the strong, spring winds blow over it, scattering its petals like snow-flakes. It derives its name from the blood-red juice in the stem. This red fluid was used by the Indians to paint their faces and color their weapons.

THE POPPY

Poppy Family

The brilliant Poppy of our gardens belongs to the same family as the Poppy which yields opium. This family of plants is distinguished by a single blossom growing on a long stalk, a large pod containing numerous seeds and a milky juice. There are several well-marked species in each branch of the family. The most common species in this country are the Corn Poppy and the Long-leaved Poppy. In both of these, the stems are long and slender and reach upward about two feet. The tints of the flowers are usually shades of red, though they are sometimes variegated. Under cultivation, beautiful double blossoms may be produced. White and purple are also seen, and the wild California Poppy is yellow or orange color.

The word Poppy is a corruption of the word «papa,» which, though the same in form, is not the same in meaning as the word which the child applies to his father, and which is derived from a Greek word. The «papa» from which the word Poppy sprang is a Celtic term, applied to a soft food, which the Celts fed to their infants. The seeds of the Poppy were boiled into a pap, to induce sleep in the child, and so the plant came to be called the «papa» and then the Poppy. This is a good illustration of the odd way in which some of our words have come down to us. While the seeds of this European Poppy are slightly narcotic, they do not contain the active qualities peculiar to opium.

Opium is the juice of a species of Poppy which especially flourishes in Asia, where it is very extensively cultivated. The plants are sown so as to stand about a foot apart. When the capsules or pods which contain the seeds, are nearly full grown, men pass through the fields in the evening, and cut little gashes in every pod. This is done with great care, and with knives so made that the cut does not sink below the skin of the pod. The milky liquid oozes out the following morning, and is removed by long spoons and collected in earthen dishes. From these it is poured into shallow platters or trays, which are tilted, so as to allow the water to drain off. The remainder is then evaporated, and continually turned until hard enough to be kneaded into balls, which are placed upon slates in large rooms to dry. Here they are tended and turned by boys, till they are dry enough to pack.

As a medicine, opium is very useful in relieving pain, but when it is indulged in to excess, it enfeebles the mind and weakens the body, and ultimately makes a miserable wreck of the user.

In cultivating the Poppy, the seeds are often sown during autumn in places where severe frosts are not to be feared; but in our Northern climate it must be sown in the spring. Poppies have an interesting way of sowing their own seed. On the under side of the pods are small holes and when the wind blows, seeds are shaken out of these little holes, just as you would shake pepper out of a pepper-box.

PHILADELPHIA FLEABANE

Composite Family

During July and August, this plant, with its yellow and pink, gives a dash of color to the moist lands. The highest leaves are smooth, oblong and heart-shaped at the base; the lowest ones are wedge and tooth-shaped. The flower heads have numerous pink ray flowers and a center of yellow disk flowers.

THE CINERARIA

Composite Family

Cineraria is the name given to a genus of plants belonging to the natural order *Compositæ*. Under it is included a variety of herbs or small shrubs, having minute flower heads, usually of a bright yellow. But there are numerous variations, and in different climates one may find species having white, flame-colored, purple or

CINERARIA.
Life-size.

HYACINTH.
Life-size.

red flowers. While it flourishes in many countries, it is most abundant in South Africa and along the shores of the Mediterranean. The class common in southern Europe is especially delicate and pretty, having silvery, finely-cut, downy tomentose foliage, and small, yellow flowers.

The name Cineraria is derived from the Latin word *cineres* (ashes, allied to the word cinder) and refers to the gray, ash-like down that covers the surface of the plant's leaves. The blossoms are formed of minute florets, congregated upon a single receptacle and surrounded by a leafy or scaly wrapper, called an involucre.

In our own country, the name Cineraria is applied to an early spring flower that is grown in most greenhouses. This came originally from Teneriffe, in the Canary Islands, but the flower, as we know it to-day, is the product of cultivation. It is popular as a decorative plant, its delicate form and color combining admirably with flowers of larger growth and more brilliant hues. It may be reproduced either by the propagation of offsets or by sowing its seeds. The former method is preferred.

When the Cineraria has finished blooming, the old flower stems should be cut down and placed in pots out of doors. As soon as the offsets are an inch or two above the earth they should — without injury to the roots — be cut off with a sharp knife, planted in small pots and placed in a cold frame. Here they must remain for a fortnight, well shaded from light, and, at the end of that time, be changed to larger pots. This must be done very gently, for the young leaves are brittle and tender.

The great difficulty in the cultivation of the Cineraria comes from the pests that so frequently attack it. The commonest of these are the green fly and the red spider, and they must be dealt with as soon as they appear. The former may be killed with tobacco smoke, and the latter is best destroyed by dusting the hairs of the plant with powdered sulphur. The plant is so very sensitive, that it is necessary to use extreme care in the treatment of it.

THE ASTER

Composite Family

THE Aster well illustrates some of the peculiar characteristics of the Composite family. The center is an assemblage of hundreds of little trumpet-shaped flowers, set as closely together as possible. In the ring around the outside are the ray flowers, but, while they each have a pistil, they have no stamens. If you look into one

of the little central flowers, you will see something like a bud, but it is really a ring of stamens with their heads together. Under these is the pollen. After a time the pistil, which likes sunshine and air, breaks through the stamens and drives the pollen with it. Then if a fly chance to alight close by, he receives a sprinkling of the pollen which he may carry to some other plant of the species.

This colony of two different kinds of flowers, which really make one, puts into practice the principles of a division of labor without which no society can thrive. The outer flowers attract attention, or do the advertising for the colony, by their conspicuous corollas. Their more quietly dressed sisters in the center furnish the pollen, without which no Asters would be produced.

But the Aster, because of its natural beauties and variations in color, has been extensively cultivated and it is possible by cultivation to develop the inconspicuous little flowers in the center into strap-shaped ray flowers like those which form the border. In this way double Asters are produced. This cannot be done all at once, and in our double Asters there still remain at the center some few disk flowers. By the pollen from these some seeds can be secured, but when the flowers shall have been so developed that none of the disk flowers remain, the plant will have to be propagated by cuttings.

There is a large number of species, but one of the most common native ones in cultivation is the New England Aster. The best known and the most valued of all is the China Aster, a summer species of which many varieties are grown, and others are being constantly introduced. This was brought from China in the early part of the eighteenth century. The plant delights in a rich, free soil. The seeds are generally sown in April in a hotbed, and the young plants transplanted in May. They flower from July till frost, and contribute much to the beauties of the flower garden. The native wild varieties have various colors and are in their full beauty in September.

"Bold are its footsteps in loneliest places,
Scaling the steep crag and climbing the height;
Blossoming over with fairest young faces,
Up to the woodlands and far out of sight.

"Light is its tread on the broad gracious meadow,
Fringing the hedge-rows with purple and gold;
Clustering softly in stillness and shadow,
Freely and freshly its fringes unfold."

THE DANDELION

Composite Family

GO OUT beneath the twinkling stars, on a clear night in early May, when the frogs are piping their sleepy yet hopeful song from the swampy pastures; then look forth upon the broad green fields at morn, when the sky bends over a verdant earth, dotted with the simplest and most cheerful of flowers. Then you can understand the full meaning of the poet Longfellow, when he said:—

> "Wondrous truths, and manifold as wondrous
> God has written in those stars above,
> But not less in the bright flowers under us
> Stands the revelation of his love.
>
> "Bright and glorious is that revelation
> Written all over this great world of ours,
> Making evident our own creation
> In the stars of earth, these golden flowers."

And surely he meant the Dandelion, for what flower is more brightly, purely "golden"? Lowell calls it,—

> "Dear common flower that grow'st beside the way,
> Fringing the dusty road with harmless gold,—"

and we are convinced that if the Dandelion were rare, it would be one of the most sought after and treasured of blossoms, for its intrinsic brightness and beauty. How delightful, however, that it is free to all, and, like the grass, "goes creeping, creeping everywhere," at home, in Asia, Europe and America,—indeed in all the temperate climes!

Though it seems a simple flower, on account of its humble, hardy ways, it is not simple to the amateur botanist, for the ordinary parts of a flower, such as petals and stamens, are hard to discover. We must first of all conclude it is a composite flower, for, looking closely, we see multitudes of fine, irregular florets. A magnifying glass will show them to be peculiar strap-shaped cups, with long curling anthers. These florets are planted in a round, light green knob, or receptacle, similar to that of the Daisy or Sunflower. The green involucre consists of long spikes reflexed, until the florets turn to arrows of down and fly away. The fruit is a little brown seed at the base of the downy particles.

It is properly a stemless plant, since the leaves grow directly from the ground, though the flower has a long, hollow stalk which affords

great amusement to the little ones, who are always delighted with the playthings furnished by Mother Nature. How they puff out their round cheeks to blow these stout little trumpets; how they enjoy turning back the ends of the tube, in segments which curl tightly, until a whole bunch of curls hangs from the pretty pale green stems! How they make rings by inserting the smaller end of the long, hollow stem in the larger end, slipping the next stem through the first ring, before bending it, thus forming links to a chain of any desired length, or, by fastening the last ring through the first one, forming a large ring made of smaller rings!

The reason for the name Dandelion (from *dent de lion*) lies in the odd notches in the leaves, which were compared to lions' teeth. The plant is valued for greens in this country, and in France it is raised and cultivated by the acre for that purpose, being harvested like spinach. The roots are said to be good for medicine, called as a drug, Taraxacum, having bitter, tonic properties. The flower has been found to be a natural barometer, as it closes at the approach of stormy weather. It has also been called the Shepherd's Clock, since it opens and closes at fixed hours. There is more of romance attaching to the rose, and the lily is more exquisite in its beauty, but for a hardy, cheerful bloom, typical of life in the temperate climes, we turn to the bright-faced, cosmopolitan Dandelion.

BONESET—THOROUGHWORT

Composite Family

This plant probably needs no introduction, especially to those who live in the country, or in small cities or towns. It is one of those plants whose medicinal properties compensate for its lack of beauty. Many children shake at the very name of it, because when they catch cold, they are compelled to drink copious draughts of the bitter Boneset tea; they consider it an added penalty of sickness.

It is usually a good medicine for malaria, and the "Break-bone" fever of the South. From the latter disease it undoubtedly acquired its name. The virtues of this plant were discovered by the Indians, who had a great knowledge of the medicinal properties of plants. It grows in the low meadow-lands, and reaches a height of four feet. It is easily recognized by its wide, lance-shaped leaves, that grow opposite, and unite at the base around the stem.

The small clustered flowers are dull white and composed of tubular blossoms. In the autumn one often sees the Boneset being gathered by boys, who carry great arm-loads home, where it is stored in the garret for the winter's use.

THE GOLDEN ROD

Composite Family

GO WHERE you will, from Maine to California, in August or September, and you will see the Golden Rod waving its plumes from the roadside, banks, and field borders. It blooms later in the season than most other flowers, and thus it is of great advantage to the bees, which, as one writer has said, "have their calendar." Their calendar, in truth, begins in the spring with the Pussy Willows and Crocuses, goes on with the Hyacinths, Columbine, Apple blossoms, Clover, and Thistles, and ends in the splendors of the Golden Rod and Aster.

The bees must have a succession of flowers all the year round, except in midwinter, or they never could get on at all. On the other hand, the flowers themselves each need a time when they can depend upon receiving their full share of attention from insects, or they might never set their seed at all. Thus are all the objects of nature adapted to the needs of one another.

The Golden Rod reaches its glory with the Asters and the Chrysanthemums, and all three belong to the remarkable Composite family. But while the Aster and Chrysanthemum are more pleasing in their cultivated forms, the Golden Rod revels in its natural, wild beauty. It lingers even into the golden days of October, and maintains its splendors till Jack Frost touches it with his icy fingers. Though closely allied to the Aster, the Golden Rod is distinguished by the single-rowed pappus and a tapering, rather than a compressed, fruit.

The species, while native in all temperate climes, are most numerous in North America. At least seventy-five different species are found in the United States, and because of the abundance, wide distribution, and showy qualities of the plant, many botanists and lovers of flowers have claimed for the Golden Rod the right to be called our national flower.

The plant thrives best in a rich soil, but like others in this vigorous Composite family, it makes the most of whatever opportunity it has and refuses to die, even when the soil is poor and dry. Its appearance, however, greatly varies with the soils in which it grows. On the dry hills, the plants are dwarfed and scattered, and the blossoms small, but when they line the outside of a garden wall they wave their heads gayly over the barrier, and their hungry roots reach underneath for the fertilizers on the other side. They delight to grow in clumps by the roadside, and they also thrive near rotting logs or rails.

There are fewer varieties of this interesting plant in Europe than in this country, and none of them claim so prominent a place in the autumn fields. One peculiar variety has cream-colored or nearly white flowers. The leaves of another kind when crushed have an odor something like anise and have been used as a substitute for tea.

THE HYACINTH

Lily Family

Among the earliest flowers to bloom in the spring are the Hyacinths. They belong to the Lily family and in their native soil are found, in the month of May, along the river banks and on the moist meadow land, where clusters of fragrant, bell-shaped flowers fill the air with rich perfume. The Hyacinth is a bulbous plant, and grows in water as well as in the moist soil, if properly cared for. It is not a constant flowerer, but continues to add to its bulbs, after the blossoms have fallen off, so that each season one plant produces several more. These bulbs, if kept in a dry place, retain their life, and when planted in pots or boxes, where they can be kept from the light until the delicate roots have had a chance to become strong, the tender leaves, which form a protection for the blossom, are full grown before the flower appears.

The Hyacinth has a six-parted perianth, of which three must be calyx and three corolla. It has six stamens and a single pistil. In the Wild Hyacinth, the six parts of the flower draw closely together and form a deep cup, which is partly filled with a nectar much appreciated by bees and other insects that live on the sweets produced in flowers. The Wild Hyacinth is generally blue or purple in color. Those which are cultivated are in delicate shades of pink, blue and white. Cultivation has resulted in an enlargement of the blossoms, the leaves of which have become double and curl gracefully like the petals of a rose.

In Haarlem, Holland, the cultivation of the Hyacinth is carried on extensively, and very beautiful, rare plants have been developed. There is found in them a great diversity of color, and the flowers are almost overpowering in the sweetness of their fragrance.

The Oriental Hyacinth, which is much prized by florists, is a native of Syria and Persia, but it has been naturalized in some of the countries of Southern Europe. It has broad leaves, inclosing a large cluster of flowers which point in all directions, and present a striking appearance.

GOLDEN ROD.
4/5 Life-size.

LILY OF THE VALLEY.
Life-size.

LARGE WHITE TRILLIUM

Lily Family

The remarkably beautiful flowers of this plant are set above a whorl of rich green leaves. They are large and white, with sometimes a tinge of green, sometimes a flush of pink, and are composed of three long, pointed petals, and a calyx of three spreading sepals. They have six stamens and one pistil. They also bear fruit,—a large, dark, purple berry. One finds these gleaming white flowers nestling in the edges of the woods, or hanging like stars above the banks of the rushing streams.

There are two other varieties—the Painted and the Nodding Trillium. The former is found in the Catskill and the Adirondack Mountains. The flower is smaller than the Great White Trillium, but it is none the less beautiful, for it is marked with fiery stripes.

The Nodding Trillium has small pink or white flowers that are sometimes entirely concealed beneath the leaves. Its delicate fragrance is one of the delights of the budding woods.

THE LILY OF THE VALLEY

Lily Family

The Lily Family is not so much noted for its size as for the wide differences between many of its members. It includes about sixteen hundred species, which inhabit chiefly the temperate and warmer regions of the globe. Among them you find not simply such pleasing and widely cultivated plants as the Tulip, the Hyacinth, and the Lily of the Valley, but such medicinal plants as the Aloe and the Sarsaparilla, and such vegetables as the Onion and the Asparagus. You might think these differed enough to make them distinct families, but in all of them the regularity and fixed plan of the flower is constant, and it is so characteristic that we have no doubt that the Onion and the Tuberose are relatives, despite their difference of odor.

The perfect flower has six petals, and the stamens are always six, opposite the clefts of the perianth. Whether they grow singly or in spikes, these features are the same. The roots are either bulbs or tubers, the fruit capsular in shape, and the leaves simple and entire.

The Lily of the Valley belongs to a branch of the family which puts out its bell-shaped flowers in clusters. The flowers are white and have the six clefts characteristic of the family. The common species grow in bushy places and in woods throughout Europe and North America. It prefers a damp soil but does not thrive in water.

You will notice one peculiarity in the flowers, and that is their drooping attitude. This is a device which some flowers of this family have to shelter their honey from the wet, and especially to protect it from certain insects, like ants. Many plants protect their honey from ants by a little bunch of hairs. The pansy and the violet, for instance, while they have smooth stalks that are easily climbed, place a tuft of silky hairs just in the throat of the flower and directly on the road to the honey, which is thus saved for the bee. This useful insect can run his long proboscis through the hairs, and reach the honey intended for him.

But instead of using hairs, the Lily of the Valley protects its honey by the droop of the blossoms. In vain do ants try to get into such flowers, for when they come to the downward slope, which leads to the blossom, they invariably tumble off to the ground. This device of hanging flowers for protecting their honey from ants, is similar to the swinging nests of the Oriole, which protects the eggs from snakes and other enemies.

Ants are not welcome visitors to these flowers, because they rarely carry the pollen to another blossom of the same species. After taking the honey from one plant, they crawl down and clamber up the one that happens to be nearest, no matter what kind it is. This plant can make no use of the pollen sticking to the ants, unless it be of the same species as the one last visited.

THE WATER=LILY

Water-lily Family

THE Water-lily, to which the pretty name "water nymph" also has been given, is well known as an inhabitant of ponds, lakes, and slow-moving rivers. It is securely anchored in the mud at the bottom by a root-stock, that is, a stem like a root, which sends the leaves and blossoms up to the surface, where they float, swaying back and forth on their long stems with the motion of the water. The leaves are large, flat, and nearly round. The blossoms are very showy, measuring, in our common American species, nearly six inches across. The many petals curve upward, forming a bowl-like flower, until almost ready to wither, when they spread out more flatly. In color they are white, blue, pink, or yellow.

Both the leaves and the blossoms have a shining appearance, due to an oil which prevents water from remaining on them and clogging the little mouths, or *stomata*, through which the plant breathes.

For the same reason these *stomata*, which are usually thickest on the under side of a leaf, that they may not be closed by the gum in the Water-lily, are on the upper side. Enough moisture is absorbed from below to prevent their drying up in the sun, and yet they can get air.

In fine weather, the Water-lily opens its flowers in the morning and closes them at night; on dull and chilly days, it does not open them at all. This is to protect the pollen from dampness, as the Water-lily does not hide its pollen away as some plants do. When open, it emits a delightful fragrance, which, together with its bright, shining color, attracts the water beetle, which is to aquatic flowers what the bee and other insects are to land blossoms, carrying the pollen from flower to flower. The bloom is short-lived. After a day or two, the stem contracts in length, as with most water plants, and the seeds are drawn down, to ripen under the water.

One member of this family is worthy of especial mention, namely, the *Victoria regia*, so called after Queen Victoria. It grows in South America, especially in the smaller tributaries of the Amazon. The leaf is often six, sometimes even twelve, feet broad, with a curious rim, giving it a tray-like appearance. These leaves are deep green above and pink below. They are so strong that two men have been supported by a single leaf. The blossom is usually about twelve inches in diameter, sometimes attaining twice that size. Reversing the habit of the ordinary Water-lily, it opens at night and remains closed during the day.

There are several varieties, differing somewhat in color. This plant was discovered in Bolivia, in 1801, by Haenke. The first cultivated blossom, which opened in 1849, in England, was presented to the Queen.

The far-famed Egyptian Lotus is also a Water-lily. One often sees the common Lotuses in fountains and artificial ponds, along with the other Water-lilies, among which they form a pleasing variety.

SOLOMON'S SEAL

Lily Family

As we walk along the roads of the springtime woods, this plant appeals to us by the graceful beauty of its bending stem. It is from one to three feet high, the alternate leaves are light green and set close to the stem. The tiny bell-like flowers grow in pairs and are not very beautiful; they are creamy white or greenish, giving

a faint suggestion of the wintergreen blossoms. However, they are suspended in an artistic way beneath the stem, to which they are joined at the axil of the leaf. The flowers hanging below and the leaf bending above make a delightful curve.

At each touch of the wind, the little bells swing to and fro, as if ringing out the glad tidings of spring. In the fall they give place to violet-blue berries. If you were to dig beneath the ground, you would find peculiar marks upon the root of this plant; they are caused by the broken-off stalks of former years, and seem like strange letters or signs, as on a seal,— hence the name.

FALSE SOLOMON'S SEAL

Lily Family

It is puzzling to know why this plant should be called False Solomon's Seal. It has some points of similarity with its cousin, but it is so very different that it deserves an individual name. The stem, as a rule, is curving, and from one to three feet high. Its dark green leaves are wavy and marked with parallel veins.

The small, white flowers are gathered in a leafy cluster, at the end of the stem, and are often very fragrant. They have six stamens and one pistil, and are divided into six petal-like parts. In the autumn they are replaced by pale-red berries. This plant is so beautiful that it would be an ornament to a cultivated garden. One striking peculiarity of the True and False Solomon's Seal is the fact that they always grow close together.

YELLOW ADDER'S TONGUE—DOG'S TOOTH VIOLET

Lily Family

This is another of the early spring flowers, and not the least beautiful of them. Indeed, nature is so profuse in the variety of her exquisite flowers, that we wonder how she can produce them all. Those who keep their eyes open while walking through the woods have a constant pleasure; it seems strange that so many people should be blind to the manifold beauties of nature.

Boys and girls should cultivate the art of seeing, for it will bring them rich rewards. What greater pleasure can there be than to follow the voice of a gurgling brook, and find unexpected myriads

of the Yellow Adder's Tongue growing on a sheltered bank! It seems as though the leaf-filtered sunbeams, that fall like golden lances, had taken root and blossomed into tangible petals. The Yellow Adder's Tongue grows from six to nine inches high. On each side of the large, russet-yellow, purple-marked flowers grow two long, lance-shaped leaves; they are pale, and mottled with purple and white.

The flower has a perianth of six spreading sepals, one pistil and six stamens. Its names are not very appropriate. It is called a violet, but it belongs to the Lily family. It is called "Yellow Adder's Tongue," but its speckled leaves are not like an adder's tongue.

John Burroughs has suggested that it be called either *Trout Lily*, because it is speckled like a trout; or *Fawn Lily*, because the leaves are not only marked like a fawn, but they stand up like the ears of a fawn when it is startled. It is to be hoped that one of these more suitable names will be adopted.

BELLWORT

Lily Family

The flowers of this plant are small and insignificant, and one would hardly notice them unless the plant were plucked, for the little bell-shaped, cream-colored blossoms are suspended beneath the curving stems They are divided into six distinct sepals, and have six stamens and one pistil. The leaves are set close to the stem, sometimes clasping it; their upper surface is pale green and the under one is bluish green. The plant grows to a height of about eight inches.

POISON IVY

Cashew Family

This plant is dreaded because of its poisonous properties. Some people are so constituted that they become poisoned by merely passing close to it, for the surrounding air is laden with its noxious breath. Other people can touch it without any bad results, but it is best to avoid the plant, as all will agree who have seen a sufferer from its poison. The face and other parts of the body swell and become scarlet, all the while itching and burning like fire.

The Poison Ivy is often confounded with the Virginia Creeper, but the difference between them is distinct. The leaves of the latter are divided into five leaflets, while those of the former have but three. Boys and girls should bear in mind this fact.

This poisonous vine, by means of its little rootlets, climbs over rocks and walls. It blooms in June, and the greenish or yellowish white flowers grow in loose clusters at the axils of the leaves. Its fruit is a small dun-colored berry.

The Witch Hazel plant is sometimes found growing close to the Poison Ivy. This is a curious fact, because the Witch Hazel extract is one of the best remedies in a case of Ivy poisoning. Nature holds disease in one hand, and a remedy in the other.

SPRING BEAUTY

Pulsane Family

Early in April, you should look in moist ground, along the edges of woods, for the exquisitely delicate Spring Beauty, and when you know the plant you will say that it is indeed well named. Its flowers are sometimes white, with pink veins, while others are pink, with deep-colored veins; they grow in loose clusters. Each plant has only two leaves, and these grow opposite each other. By « opposite » is meant that they spring from the same point on the stem, but are on opposite sides of it. There are five petals in the corolla of the Spring Beauty, but only two sepals in its calyx. There are five stamens, but only one pistil.

You will notice, too, that the style of the pistil is divided into three parts. The stem above ground is quite pink, and sometimes even red, but when you pluck the flower you will see that there is a very long, white part of the stem under ground, and you may think this is the root. If you dig down six or eight inches, however,— and a good stout knife or a trowel is useful for this purpose,— you will come upon a small tuber or bulb of very peculiar shape, with the small, fibrous roots growing from it. So the long, white part was not a root at all, but an underground stem.

If the day is cloudy, you will notice that this flower closes, and one of the most disappointing things about the plant is that it wilts so soon after you gather it. But do not throw it aside too quickly, — put it where good, strong sunshine will reach it, and you will be surprised to see it unfold again.

The botanical name of the Spring Beauty is *Claytonia Virginica.* Sometimes, by means of the scientific names, botanists keep alive the memory of men who have spent a great deal of time in studying plants. They often give to a plant the name of some eminent man, and for a second name, join with it an adjective that tells something about the plant. In the case of the *Claytonia Virginica* the second

word is the Latin name of the place where it was first found. The first name is like your surname, or family name; the second is like your Christian, or given name. But you see the two parts are differently arranged, as that which comes first in your case is last in the flower's.

After you have admired the flower, which is worthy of your praise, you may be struck with the appearance of the root. The bulb, so large and irregular in shape, between the small roots and the long, slender stem, is really a sort of storehouse or pantry, in which food is stored up for the plant's use. If you were to transplant one of these plants into a pot of sand, which contains no food for plants, you would find that it would live for some time. Then if you should examine the bulb, you would see that it had shriveled up, and was small and empty.

Our garden vegetables, such as the carrot, beet, and turnip, are good examples of the same thing. They have large, fleshy roots, and you know that if they are left in the ground all winter they will grow the next year, but will go to seed. After they have done this, you will find that the root has shriveled up, and that the plant has been living the second year on the food it stored up during the first.

So you see it is not alone the squirrels and the bees that work to lay up a supply of food when it is plentiful, so as to be prepared for a time of scarcity, but plants and vegetables, too, have work to do for the future as well as for the present. When more plant food comes near to their roots than the plants need, many of them store it up for future use, and so are able to live over a dry season. But there are some plants, just as there are some people, which, during times of plenty, live the more luxuriantly, and make a great display of showy blossoms, only to suffer and fail in times of adversity. Many of us would laugh if we were told that among the many interesting things that plants can teach us we might learn a lesson of thrift and economy from a carrot.

RED=OSIER DOGWOOD

Dogwood Family

THIS is a gaudy shrub, from three to six feet high; it grows in wet places, and is more usually found in the North. One's attention is quickly caught by its bright purple branches that shoot like slender flames amid the foliage.

The rough ovate leaves are rounded at the base and short pointed, with whitish underparts. The small white flowers have four spreading petals, and a calyx of four sepals; they are arranged in flat

clusters and have four stamens and one pistil. Later in the season, the flowers give place to lead-colored berries.

There are three or four varieties of the Dogwood family, all of which add greatly to the color scheme of the woods. One genus that is worth mentioning is the Round-leafed Dogwood. Its bark is used as a tonic, and also yields an extract that is similar in its effects to quinine, although not so strong. The Chinese and the Creoles are said to use the peeled twigs to whiten their teeth.

BUNCH=BERRY OR DWARF CORNELL

Dogwood Family

In our woodland journeys, one of the pleasant surprises in store for us is the Bunch-berry. In June, it bears, at the tip of each stem, what at first sight appears to be a large white blossom; when, however, we examine it closely, we find that what seems to be the white petals, are only involucre leaves that surround the little green flowers in the center.

The stem of the Bunch-berry is five to seven inches high, and has ovate, pointed leaves, the upper ones being gathered in a whorl. The calyx of the tiny flowers has four small teeth. There are four stamens and one pistil. But the attractive flower is not the only interesting thing about this plant; later in the summer bunches of bright scarlet berries appear.

One who has toiled hour after hour up a fragrant mountain side cannot forget the thrill of pleasure that the sight of these brilliant berries produces. They seem like torches held by fairies. Sometimes, even in the late summer, a few white flowers nestle among the berries, making a striking contrast of color. In the Scottish Highlands this plant is called "The Plant of Gluttony," because it is said to produce a keen appetite. It is also related that the Eskimos use it as a food during the winter months.

EARLY SAXIFRAGE

Saxifrage Family

At the beginning of April we find this flower growing in the crevices of rocky cliffs. At first sight it reminds us of drifted snow, loath to leave its shelter. The stem is from four to seven inches high, with wedged-shaped leaves clustered around the root. The flowers are white, clustered, and small, with a five-cleft calyx, five petals, one pistil, and ten stamens.

MITRE=WORT, OR BISHOP'S CAP

Saxifrage Family

In April and May we find this flower growing upon the hills and in the woods. Its crystal-like flowers are fragile looking and exquisite, having five slender petals with one pistil and ten stamens, and a short, five-cleft calyx.

Its hairy stem is ten inches high, and the lobed, heart-shaped leaves grow opposite one another. The name Mitre, means "turban," or the high, two-leaved head-dress of the medieval bishop, and is derived from the shape of the pistil.

THE CULTURE OF THE ROSE

The "little cottage in a bower of roses" has been the dream of many a romantic young person, but such sweet surroundings are not attained without labor. Suppose the little cottage to be standing bold and bare in a monotonous little yard,— let us help you to plan to make it the ideal one mentioned.

Take cuttings of choice young Rose bushes — not in the soft state, but when the woody part has attained some hardness, and when the young shoot (of which the cutting is made) has developed a flower bud about the size of a large pea. There is no need of cutting at a joint, though European gardeners invariably do so.

Put a number of the cuttings into a plate or large saucer of sand, about an inch deep, then water with a very fine sprinkler until it is like mud. Put the vessel on a shelf in a sunny window, and keep the sand constantly saturated. The average temperature of the room should be from seventy to eighty degrees,— never below sixty-five.

In about three weeks the Roses will be rooted and ready for potting. The pots should be from two to three inches in diameter, and the plants should be treated with especial care as to shading and watering for several days. When the spring is well advanced, they may be set out in the ground, and soon in your case, even though on a small scale, "the desert shall blossom as the rose."

Now take another case, — suppose you have just taken up your abode in an old mansion, whose garden runs wild with neglected Rose bushes, whose flowers are of inferior size, and have no variety in coloring. You may take a leaf bud from a choice variety of Rose, insert it in the stem of any new shoot of the old Rose bush, and the branches afterward proceeding from it will bear the new and

more choice species of flower. Indeed, on every separate shoot of a Rose bush, you may bud a distinct variety if you wish, and each will retain its own characteristics of color, form, and fragrance. But this is a very delicate operation.

The stock to be budded upon should be in a thrifty condition, so that the bark can be raised easily from the wood. Rub off all leaves and shoots below the spot chosen, and make a lengthwise incision through the bark to the wood, then one crosswise near the upper end of the first.

Take a shoot of the chosen variety, cut from it a healthy bud, with as little wood as possible. Lift the edges of the bark, insert the bud and press the bark of the stock into place. If any part of the bark attached to the bud extends above the cross incision in the stock, it should be cut off. The tying material is cotton wick, but Raffia bark is preferable, as it entirely covers the wound, and excludes the air and water. In two or three weeks the wrapping may be removed, and if the budding has been done in June, the plant will make some growth the same season; if in late summer or early fall, not before the following spring. When growth begins, the stem should be cut back just above the new bud, that the latter may receive the full benefit of the food supply from the root.

The selection of varieties is, of course, very important. In the northern states, the Hybrid Perpetual Rose is "a thing of beauty and a joy forever," but in a southern climate it becomes enervated and feeble. Evergreen and ever-blooming Roses, like the Tea, Bourbon, and Bengal, are beautiful in the far South, where frosts are slight.

The best kind for all sections is a new class of Roses known as the Hybrid Tea, of which the American Beauty, a bright crimson, has the most delightful odor, and La France is the most attractive in color. Roses need particularly rich, well-drained land. The soil should be dug up to the depth of one foot, at least, and well mixed with cow manure or bone dust, the former being preferable.

The Hybrid Perpetual or Hybrid Tea Rose needs frequent pruning, while the Monthly or Tea Rose only calls for the thinning out of old stocks in the spring, or the occasional pinching off of an overabundant shoot, whose presence would destroy the symmetry of the bush.

The Rose bug is the terror of those who love the "queen of the garden," and is the Rose's most insidious enemy, though the aphis, or green fly, and a certain little red spider, are also troublesome. The fly is a small, grayish-brown insect about half an inch long, resembling a cockroach. It seldom shows its colors openly, but makes hiding burrows at the roots, and these burrows soon destroy the life of the bush. It would be a paying investment to employ some bright-eyed

boy, at a salary of one cent each, to kill the little pests, for by this method you may soon get rid of them.

To remove the aphis, or better, to prevent it, tobacco in some form should be applied. The fumes may be used, or the leaves may have tobacco dust sprinkled on them, though probably the most effectual way, for a small number of plants, is to wash them in water in which tobacco leaves have been steeped. A little flower of sulphur scattered over the leaves will insure against mildew. The red spider's presence shows the atmosphere has been too dry, and the leaves should be sponged and the air kept more moist.

Suppose you wish to adorn the interior of the first "little cottage," during the winter, with some of the brightness and fragrance of June. Rose plants, in five-inch pots, may be obtained from the florist, at from four to six dollars per dozen. The pots must be well perforated, as, in order for Roses to flourish in winter, the soil should be well drained.

The earth used in the pots should be good, loamy soil, well mixed with cow manure. Syringing, which is the best method of watering, should only be done once a day, the forenoon being the preferable time. A top dressing, applied every three or four weeks, is very helpful. This should consist of half an inch of compost, made up of cow dung, fresh soil and a small amount of pure bone dust. The soil should be stirred occasionally to give the roots air. About February, liquid manure should be used in watering, and, soon afterward, light pruning should begin.

Some of the finest winter Tea Roses are the Marshal Robert (pale yellow), the Bon Silene (carmine) and the Bride (white). The Hybrid Perpetual is harder to raise in winter, and had better be left for outdoor purposes, at least by amateur gardeners.

Beautiful Climbing Roses are the Marèchal Neil (yellow), and the Gloire de Dijon (salmon pink). They all need frequent fertilizing, and will amply repay one's most tender care, with their beauty and grateful fragrance.

AGAVE

The Century-plant or American Aloe was introduced from Spain in 1561. It lives from ten to fifty years before flowering. When it is ready to bloom, a large scape grows up rapidly in the center of the plant, and develops a large compound cluster of flowers. The plant is of slow growth and consists of a number of light green, fleshy leaves tipped with a sharp spine, and, in some species, edged with spines. It is called Maguey in Mexico, where the natives use

the sap for making a fermented liquor, resembling cider, called pulque. The leaves furnish an extract used as a substitute for soap; and the flower scape or stalk when withered is sliced and dried to make razor-strops. Rope and thread are made from the fibers of the leaves.

ALLSPICE OR JAMAICA PEPPER

The *Eugenia Pimenta*, a tree-like plant of the East Indies, produces fruit which combines the flavors of cloves, nutmegs, and cinnamon. The tree rises to a height of from twenty to thirty feet and bears oval leaves and small flowers. The fruit is much used in cooking and in the manufacture of aromatics. A tree produces on an average 100 pounds of dried fruit.

ALOES

A genus of Liliaceous plants varying in height from low herbs to bushes. The dried juice of several of the species forms the well-known purgative medicine. The aloes of commerce is known as the Socotrine aloes, which comes not only from the Island of Socotra, but also from Zanzibar and East Africa. Another variety is the Barbadoes aloes from the West Indies and South America. Natal aloes from the South of Africa yields the greatest part of the supply. The bushes are used to form hedges in the East Indies. In the East it is a sacred plant among the Mohammedans, and, when one has made his pilgrimage to Mecca, he hangs a branch over his door to indicate that fact.

AMARANTH

A plant of the genus *Amarantus* which abounds in tropical countries. The commonest plants of the genus are Love-lies-bleeding, Cockscomb and Prince's Feather. It is also a fabled flower which was believed never to fade, hence it is an emblem of immortality.

ANISE

A plant of the order *Umbelliferæ*, native to Egypt but the greater portion of the seed comes from Spain and Malta. Its seed possesses an aromatic oil of anise which is much used in making cordials, and in medicines for carminatives and flavoring.

ARROWROOT

There are several varieties of this article of food, but the name properly belongs to the product made from the Rhizomes of the genus of plants called *Maranto*, which is cultivated extensively in the West and East Indies. It is a form of starch and it takes its name from the fact that it was extensively used by the Indians to cleanse wounds made by poisoned arrows. The substance known as English Arrowroot is made from the potato. Brazilian Arrowroot or Tapioca Meal is usually called Cassava. The substance is prepared by taking the root-stocks of the plant, which are usually about twelve inches long and an inch in diameter, peeling them and grinding to a pulp. This is treated in water, the starch extracted and evaporated in the sun. A fine product known as Oswego Arrowroot is made from Indian Corn.

ASAFŒTIDA

This is a substance made from the sap of a genus of Umbelliferous plants known as *Ferula*, grown in Persia and Afghanistan. It supplies the drug which has a very strong odor of garlic and a bitter taste. It is used in medicine as an anti-spasmodic.

ARTICHOKE

A plant resembling a thistle belonging to the order of *Compositæ*. The receptacle of the large flower-heads is used as an article of food. There is another variety known as the Jerusalem, a species of sunflower of which the tubers are eaten boiled like potatoes, or in the form of salad. It has nothing to do with Jerusalem, as that name is a corruption of the Italian, *Girasole*, which means sunflower, to which family the plant belongs.

ASPARAGUS

This well-known vegetable belongs to the Lily family. It is a native of Europe and has been much improved by cultivation. It is planted very deep in heavily fertilized beds and the young, tender shoots are the portion that is eaten.

AZALEA

A genus of plants belonging to the Heath family cultivated for their beautiful and fragrant flowers, which are formed in large clusters and are of many colors. They grow well in shaded places.

BASIL

This is the name given to an aromatic plant with long leaves and whorled flowers. It is used as a seasoning and in medicine. The flowers are labiate or lip-shaped. The plant has been much esteemed in Eastern worship. The roots of the plant yield an aromatic oil known as Basil Oil.

BEET

This useful vegetable and fodder plant is of biennial growth with a nap root and usually large and somewhat flesh-colored leaves. There are four principal varieties, the common beet; the chart; the sea-beet; and the mangel wurzel. The latter is a large coarse beet which is usually raised to feed cattle. The yellow and red beets are used as articles of food for table use. The white beet is used in the manufacture of sugar. In this process the roots are grated to a pulp, the juice is separated, filtered and concentrated by evaporation, and yields the product known as beet root sugar. Manufacture is extensively carried on in Europe, where it had been developed by the patronage of Napoleon in 1810 and the researches of Count von Arnim, a German chemist. Experiments have been made in the United States and it has been found that a zone extending from the middle states from the Atlantic and Pacific is well suited for the raising of the sugar beet. In 1899 the product of the manufacture of root sugar from fourteen states and territories extending from California, Oregon and Washington to New York, was 163,500,000 pounds of sugar having a value of $7,250,000, and molasses and other products having a value of $100,000.

BEGONIA

This is a large family of plants cultivated for their foliage and flowers. One peculiarity of the plant is its unsymmetrical leaf. The midrib does not pass through the middle, but to one side so that one division of the leaf is much larger than the other. A great many varieties have been produced by cultivation and crossing.

BELLADONNA OR DEADLY NIGHTSHADE

A CULTIVATED plant in America which grows wild in Europe. The entire plant is very poisonous. It grows to a height of from four to five feet and has a peculiar shining black berry. The most convenient antidote for poisoning by Belladonna is vinegar. The active principle is Atropin. It is used in medicine to relieve pain, to check profuse perspiration, and by oculists to rest the eye by paralyzing the nerve of accommodation which allows the iris to contract or dilate according to the light. The result of the application in this case is enlargement of the pupil.

BERGAMOT

A GENUS of plants or trees similar to Pears and Citrons. Bergamot Oil is made from the Citron. The fruit is shaped like a Pear, yellow in color and from it is obtained oil much used in perfume, and extracted by pressure or distillation. It is also a popular flavoring extract and an ingredient in pomades, essences, and cologne.

BLACKBERRY

Rubus Fruticosus

A PLANT with prickly stems, bearing leaves, flowers, and fruit resembling those of the raspberry, except that the latter is black in color, whence the name. A very profitable fruit for cultivation.

BUCKWHEAT

A GRAIN of easy growth on scanty soil. A bushel of the grain weighs about 48 pounds and the average crop is 40 bushels to the acre. It is much used in the raising of bees as it is rich in honey. It is grown extensively in the states of New York and Pennsylvania. It is usually eaten in the form of cakes. It is also fed in the raising of chickens. In 1902 in the United States, 14,529,770 bushels were produced having a value of $8,654,704. The average yield to the acre all over the country being 18.1 bushels. The average product per acre being $10.75.

BULRUSHES

THIS is the name loosely applied to a variety of different species of aquatic plants that are found growing abundantly in and around marshy places. It is properly restricted to the plants from which the bottoms of chairs and similar objects are woven. Sometimes it is inaccurately applied to the cat-tails or *Typha Latifolia.* The Bulrush of Egypt is the Papyrus plant which formerly was used as a substitute for paper. The plant is largely used in Asia as a thatching for roofs.

BURDOCK

A PLANT belonging to the Composite family and characterized by large Rhubarb-like leaves and a compound flower head that forms a bur. The ends of the seeds in this turn over to form little hooks, by means of which they adhere to the clothing, to the fleece of sheep, and the hair of animals, and are thus transported and widely distributed. The root is very long which makes it a very troublesome weed. It is said that the root has certain medicinal properties and is sometimes applied as a remedy for rheumatism and skin diseases.

CABBAGE

A LARGE plant belonging to the *Cruciferæ* or Mustard family. It is used as a vegetable and as a fodder for cattle. It forms a large compact head supported upon a stout stalk. It is perennial forming its seed in the second year. The red cabbage is usually pickled. A very large variety called the cow-cabbage or tree-cabbage, is a coarse form raised for cattle and sometimes attains the height of twelve feet. As an article of diet it is boiled or made into sauerkraut or salad. The raising of cabbage forms an important industry in the southern states whence the northern market is supplied. It is often attacked and seriously injured by the caterpillars of the cabbage butterfly.

CALAMUS

A SPECIES of eastern plants related to the Sweet Flag and the Lemon Grass of India. They climb by means of strong hooks or reversed thorns upon the leaves. The rattan canes are obtained from this species and are used as walking sticks. The resin of one

variety forms the Dragon's blood of commerce. The stems sometimes reach a length of 200 feet and have supplied the cables of which rude bridges have been built. They are very strong and lasting for this purpose. The Sweet Flag is found everywhere in temperate zones, and yields an oil that is of service in the manufacture of perfumes, while the sweet scented grasses of India, which belong to the family, are burned as a sort of incense.

CELERY

A plant closely allied to Parsley. When growing wild it is bitter, sharp-tasting, and poisonous, but it has been cultivated to form a wholesome vegetable. The stalks are either red or white. They are whitened or blanched by covering them with earth which prevents the action of the sun upon the chlorophyll or green-coloring matter, and this whitened portion of the stock is the edible part. Certain properties of celery are useful in medicine for nervous diseases. The plant belongs to the Umbelliferous family.

CHAMOMILE

This plant is a native of southern Europe but is largely cultivated in America. It bears white flowers with a yellow center in a clustered head. The flowers are compound and the plant belongs to the Composite family. It is much used in medicine in the form of an infusion, as a stimulant and as a poultice.

CHICORY

A plant common to Europe and America and belongs to the Composite family, and is occasionally seen growing wild. Its root is fleshy and tapering. The flowers are bright blue. The large root is roasted and ground and used as an adulterant of coffee. The roots also serve as a food for cattle. The blanched leaves form a salad. The Chicory in coffee may easily be detected by throwing the ground coffee upon water. The true coffee, being light, floats upon the surface, while the Chicory, being heavier, slowly sinks to the bottom. It may also be seen in coffee under the microscope where it presents a very different appearance from coffee.

CHRYSANTHEMUM

A plant of the Composite family and a close relative of the Marguerite or Ox-eyed Daisy, Marigold, and others. It has been very much improved in appearance and color by cultivation, and there are at present hundreds of different varieties. It is a late-flowering plant and comes into bloom late in the fall when other flowers are done. It is the national flower of Japan, where it is highly esteemed. The 16-petaled, open Chrysanthemum is the Imperial Emblem of that country.

CLEMATIS

A genus of plants widely distributed both in Europe and America and possessing many different varieties. Some of them are among the earliest blooming wild-flowers, and many have been cultivated to an enormous size. Sometimes these flowers of various colors are six inches in diameter. They are members of the Crowfoot family. The flowers have no petals, but the sepals are bright colored. Among the common forms is the Virgin's Bower which has white blossoms almost covering the hedges in early spring. Indians are said to use the root of the Clematis as a stimulant to be given to exhausted horses.

COFFEE

A familiar beverage, made from the seeds of the coffee shrub indigenous to Abyssinia and the southern parts of Arabia. The tree, which is not allowed to grow more than six or eight feet in height, thrives well in warm, moist lands, and yields its first crop in the third year. The shrub also grows on well-watered mountain slopes, even at a high elevation, so long as there is no frost. The dietetic value of coffee chiefly depends upon the alkaloid caffeine which it contains in common with cocoa, tea, etc. This is developed by washing the bean, an operation of great nicety; and after grinding it should be excluded from the air, so as to preserve its aroma and refreshing qualities as a drink. The chief varieties are the Java, Rio, Jamaica, and Mocha brands.

COLCHICUM

A SPECIES of plants belonging to the Lily family and including the common Saffron. The flowers appear in the early spring and closely resemble the Crocus. The flowers are pale lilac in color and are to be seen from August to October. The medicinal properties are to be found in the bulb and the seeds and it is largely used in cases of gout and inflammatory rheumatism.

COTTON

THE hairy covering of the seeds of various species of *Gossypium*, a genus of plants which belong to the mallow family. The plant is indigenous to China, India, Brazil, Egypt, and the southern regions of the United States. Next to wheat, corn, and rice, cotton is perhaps the most valuable to man in the manufactures. The cotton plant, which is cultivated only in tropical or subtropical regions, is a herbaceous, or shrubby perennial plant, growing from three to twelve or fifteen feet in height. It has large and showy flowers, and it is from the long filaments of the seeds that cotton is derived. In each pod of the plant are several chambers which break open and disclose a globular mass, known technically as the "cotton boll" covering the seeds. The cotton, when cleaned and worked up, is manufactured into all kinds of fabrics, for domestic and for fancy purposes, such as calicoes, cambrics, shirtings and also as muslin, laces, etc. Yarn, of the finer sorts, is made usually from Egyptian and the sea island cottons. The manufacture and consumption of all varieties are now enormous; the production in the United States alone for the year 1899 being 9,345,391 bales (of an average weight of five hundred pounds). The world's consumption for the same year was estimated at 13,500,000 bales. The chief states growing cotton in America are Texas, Georgia, Mississippi, Alabama, North and South Carolina, Arkansas, Louisiana, and Tennessee.

COTTON-SEED CAKE AND OIL

THE seeds of cotton are rich in oil, which is now largely used as a substitute for olive-oil, as a lubricant. In its preparation the seeds are treated in the same manner as linseed, and yield a brownish fluid oil used for general purposes. Oil-cake is the refuse of cotton and flax seeds, or other vegetable substance from which oil has been expressed. Compacted into a solid mass, it is used as a manure, and especially as food for cattle.

COWSLIP

A genus of plants closely resembling the Lily and belonging to the Primrose family. It is a wild flower in England but is cultivated in the United States. Its flowers are in umbels or clusters, and are a peculiar yellow with a faint odor. The American Cowslip is known as the Shooting Star. The blossoms are frequently used in England mixed with ale and wine with the belief that the flowers are anodyne.

CROCUS

A genus of beautiful plants which are commonly cultivated in gardens. Their roots are corms and the leaves are grass-like, the flowers appearing before the leaves. Some species bloom in the spring; others in autumn. The Saffron of commerce is obtained from the orange-colored stamens of the flowers of one of the species and is largely used as an orange dye.

CUCUMBER

The original home of this plant was Egypt and the south of Asia. The seeds were introduced to Europe by the Crusaders, and to America immediately after its discovery. It is a trailing vine bearing monœcious flowers, that is, some of the flowers upon the plant have pistils only and others have stamens only. Fertilization of the flowers is brought about either by insects or by the wind. The fruit is long and fleshy and incloses a great number of small seeds. It was cultivated in very early times for it is mentioned in the book of Numbers. The large fruit is used as a salad and the small fruits are pickled and are known as Gherkins.

CURRANTS

A small raisin (seedless), or the dried berry of a seedless variety of grape, imported from the Levant. It derives its name from the city of Corinth, Greece, whence currants were probably first imported. They are also brought from Zante and Cephalonia, and other of the Ionian Islands, and are largely used in cookery as an ingredient in puddings and cakes. They are of three varieties — the red, the black, and the white currant; all of which are the acid fruit or berry of the genus *Ribes* which includes also the gooseberry.

DAHLIA

A GENUS of plants found in Mexico by the Swedish botanist, Dahl, after whom the genus was named. They are very showy flowers and in the cultivated state are grown both single and double. The roots are tuberous and are planted in the spring much in the same manner as the potato. The plant belongs to the Composite family and from the single species have been produced very many varieties which differ in form, color, and size.

FENNEL

FENNEL is an aromatic umbelliferous plant much cultivated for its agreeable odor and fragrance. It is a tall, smooth-stemmed herb with decompound leaves and bright yellow flowers. The seeds are used in medicine and the plant generally in veterinary surgery. Fennel-water is a spiritous liquor made from the seed. The varieties are: Giant-fennel, Hog-, or Sow-fennel, Sweet-fennel, and Common-fennel.

FOUR O'CLOCK

THE Marvel of Peru is an ornamental flower which opens its flowers in the afternoon and they remain open until the next morning. This peculiarity of flowers in opening at different hours of the day has been taken advantage of by ingenious gardeners who have made a flower-clock. This is a collection of flowers placed in a circle in the order of opening and shutting at certain hours of the day.

GOOSEBERRY

THE Gooseberry is a member of the Ribes or Currant group of the Rose family. The bushes are low and thorny. The leaves are much cut, and the fruit, which is large, is covered with coarse hairs. The fruit is large and globular and has led to the seemingly contradictory statement that the berries are green when they are ripe, and red when they are green. The fruit of the wild varieties is seldom eaten.

GOURD

IN BOTANY this term is applied to the forms of fruit borne by the Squash, Melon, and Pumpkin. It is restricted in another sense to the fruit of the Lagenaria, which presents a number of varieties, and forms. Such are: the bottle, club, and trumpet, gourds. The latter is the Calabash, which when dried and hollowed is used as a vessel to hold water. These are often decorated by scraping and staining. They will withstand heat for sometime and are often used for boiling vessels. The mock-orange is also a form of gourd, known as the egg-gourd. One variety of gourd furnishes a net-work of tissue which is used as a sponge or cloth and the plant called the Towel or Dish-cloth Gourd.

HEDGE-MUSTARD

Sisymbrium

A GENUS of plants belonging to the order *Cruciferæ*. They are characterized by small yellow or white flowers whose petals are arranged in a cross-like form: the seeds are contained in pods of a roundish or 6-angled shape.

HELIOTROPE

A GENUS of plants belonging to the order *Boraginaceæ*, often bearing fragrant flowers. That usually cultivated is the Peruvian heliotrope. They thrive well in rich, light soil and are most usually propagated by cuttings.

HENBANE

Hyoscyamus

A GENUS of plants belonging to the order *Solanaceæ*. The plant contains an alkaloid, *Hyoscyamine*, which is of medicinal value and is an active poison. When dropped into the eye the effect is the same as that of belladonna; it dilates the pupil.

HOLLYHOCK

A PLANT of the Mallow family, with a tall, straight stem; heart-shaped, wrinkled leaves, five to seven in number, bearing large, showy axillary, almost stemless flowers.

HOPS

Humulus Lupulus

A PERENNIAL plant of the order *Cannabinaceæ*, the only plant of its genus. It has long twining stems, 3-5-lobed, rough leaves. The flowers are diœcious — male and female. The ripened cones of the female flowers are the parts used in brewing. In 1900 the hop crop of the U. S. was estimated at 208,000 bales of 180 lb each.

HOREHOUND

HOREHOUND or Hoarhound is a member of the Labiate or lip-shaped family. Its stem is square, hoary or white, whence the name, and the flowers are arranged in whorls. It is much used in medicine as its oil is said to be beneficial in coughs and colds.

HORSE-RADISH

HORSE-RADISH is a member of the *Cruciferæ* family. It is a perennial plant sending up each spring its long stalks from cylindrical roots. These roots are dug in the spring and when grated form a pungent, agreeable condiment. It is used in medicine, both internally and as a poultice.

HYDRANGEA

HYDRANGEA, or Snowball, is a cultivated plant, much admired for its large showy white, blue or pink flowers. The plant belongs to the Saxifrage or Rock-breaking family. There are 43 species in this group; all of which present marked differences, and vary in size from a small tree to a low pot-plant. The plant is a native of China and Japan.

HYSSOP

THE Hyssop is a member of the Labiate family. It is reared in gardens and esteemed for its medicinal properties. In religious exercises, the branches were used to sprinkle water upon a congregation as a form of purification. The plant is perennial, of a shrubby nature and bears beautiful blue flowers.

ILEX

A genus of trees and shrubs of the natural order *Ilicineæ*, or holly tribe. It is a native of Southern Europe and Northern Africa. Its wood is very hard and is used extensively for manufacturing purposes.

INDIGO

A substance obtained in the form of a powder from leguminous plants of the genus *Indigofera;* used as a blue dye. These plants belong to the natural order *Leguminosæ*, sub-order *Papilionaceæ.*

IPECACUANHA

The dried root of *Cephaëlis Ipecacuanha*, a small shrubby plant, a native of Brazil, the United States of Colombia, and other parts of South America. There are three varieties, the brown, red, and gray—differences due to nothing more than age, place of growth, or method of drying. It is emetic, purgative, diaphoretic, and is much used in medicine. It is in the bark of the root that the active principle (emetine) lies, and in good specimens it amounts to 14 or 16 per cent.

JALAP

The common name of the root of the *Ipomœa*, a genus of *Convolvulaceæ.* It takes its name from Jalapa or Xalapa, the export town of Mexico. The plant is of a twining, herbaceous growth and bears beautiful deep-pink flowers. The root is purgative but is griping and nauseating. It is found most abundantly in the higher table-lands of Mexico, sometimes 16,000 to 18,000 feet above sea-level. The roots vary in size from that of a hen's egg to a man's fist. They are rather turnip-shaped or ovoid.

JESSAMINE

The Jessamine is a favorite on account of the fragrance and beauty of its yellow or white flowers. The leaves are either compound or single. The flowers are tube-shaped ending in a spreading or flattened limb of usually four petals. The oil is used in the manufacture of perfumes. There are about 100 representatives in the genus *Jasminium*, order *Oleaceæ.*

LARKSPUR

This cultivated plant belongs to the genus *Delphinium.* It takes its name from the peculiar spur-shape of the blue flowers. It is common in gardens. The chief varieties are, the Common, or field; the Rocket, and the Bee Larkspur.

LAVENDER

The Lavender is a shrub growing from two to four feet high, with hoary leaves and grayish blue or lavender flowers. The plants contain an aromatic oil much used in perfume. The dried leaves are used in clothes and linen chests. The plant has medicinal properties also; the tincture of lavender being officinal. The oil is used in the manufacture of Florida water, and toilet preparations. It belongs to the genus *Lavandula.*

LEGUMES

Clover, Beans, Lucernes or Alfalfa.

The Leguminous Plants include a great many useful food-plants. Their name is taken from the fact that the seeds are inclosed in a legume or pod. The flowers are of a peculiar form like that of a butterfly, as may be seen in the case of the Sweet Pea. This form of flower is known as papilionaceous, from the French, papillon, a butterfly.

The Clovers form a group in this family under the class-name of *Trifolium*, which refers to the three leaflets in the compound leaf. They are low herbs, numbering about 200 species in the world, 50 of which are found in North America. They are used as food-plants for animals. As their roots are so long and pierce to such great depths in the earth they are often sowed and ploughed under to fertilize the ground. The Red Clover is the *Trifolium pratense*, the White Clover is *Trifolium repens*, and the Alsike is *Trifolium hyoridium.* The Red Clover seed is often mixed and sown with the seed of grasses for a hay-crop. Alsike or Swedish Clover is best suited for cold climates and moist, heavy soils. The White Clover is best suited for pasturage, as it is a perennial. Many varieties are useful in the production of honey. The other varieties such as Hop Clover and Zigzag Clover are merely weeds.

Lucerne is a plant much used for pasture and forage. It is especially cultivated in Southern California. It is much liked by animals and will yield several crops in a year. It came into the Western states from South America and is often called Alfalfa.

The Bean is a member of this group and is used as food for man and beast. It has been improved largely by cultivation and many varieties exist. The common Kidney-bean, Haricot or French Bean, String-bean and Pole-bean form one group. The Lima-bean, Carolina bean, Sugar-bean and Butter-bean form another. The Dwarf, Field, Bush, Navy, Pea and Six-weeks Beans are classed together. The Scarlet-runner and the Prairie-bean are cultivated as flowers. The bean occupies a high place in animal economy, on account of its extremely nutritious qualities. It is rich in legumin, a substance very like casein in cheese; and there is also a great quantity of starch present. The name bean is often applied to seeds which resemble beans in shape but are not at all related to them.

Peas are vegetables of great antiquity. They are marked by their pinnately compound leaves ending in a tendril. The vines are climbers and the flowers are usually white and papilionaceous. The seeds are used both green and dry. In some varieties which are stringless, the pod also is eaten. A great many varieties have been formed by cultivation. The very large seeded forms are useful for fodder, and the smaller-seeded varieties, as the French Pea, are more esteemed for table use.

The Beach-pea or Sea-pea is a common form of weed found on the seashore. Its flowers are usually blue and red.

The Sweet Pea is much cultivated for its fine flowers, which vary through almost all possible shades and tints.

The Vetch is much cultivated for fodder. Its leaves are pinnately compound but the leaflets are very small. It is supposed to be the tare of the Bible.

LETTUCE

This group of plants, the *Lactuca*, is best known by the garden representative much used as a salad-plant. It grows so much like cabbage that one variety is known as the cabbage-lettuce. The wild varieties are the coarse weeds of rank growth. The juice is milky-white. The chief wild forms are the *Mulgedium* or Blue Lettuce and the *Lactuca Canadensis* or Wild Lettuce.

LICORICE

LICORICE or Liquorice is a corruption of *glycyrrhiza*, a Latin word meaning "sweet root." The word has no connection with either "liquor" or "ice." The juice of the root of the *Glycyrrhiza glabra* grows to a length of several feet and is much used in throat and catarrhal troubles. The juice is expressed or squeezed out from the roots, evaporated and the solid, black residue is run into sticks. The root itself is found in drug stores in bundles of yellow wood with brownish rind. It is much cultivated in Europe, Asia and Africa. The imported root is manufactured in the United States. The *Glycyrrhiza lepidota* is called Wild Licorice in America but does not yield the same useful substance as the Old World variety.

LILY

THE Lily family or *Liliaceæ* contains about 2500 species, including herbs, shrubs and trees. The plants are monocotyledonous, with endogenous stems. The flowers are regular and with one exception have always six stamens. Many species, such as the Lilies, Tulips, and Hyacinths, are beautiful and showy garden plants, some, like the Allium or Garlic, are edible.

The wild, orange-red Lily or *Lilium Philadelphicum* is a native of America. Its flowers grow erect and the sepals are not curved back. It grows abundantly on sandy soil. The southern Red Lily or *Lilium Catesbæi* has recurved sepals and the flowers are solitary.

The Canada Lily or *Lilium Canadense* is common in the north and has several nodding flowers in a group and the sepals are curved.

The American Turk's-cap, Swamp Lily, or *Lilium Superbum* bears from 20 to 40 flowers in a panicle or cluster. It is found growing in low places in the north.

The Washington Lily or *Lilium Washingtonium* is found on the Pacific slope, bearing 20 large, white, and fragrant flowers in a cluster. Other Pacific coast varieties are the Panther Lily and Humboldt's Lily.

The Turk's-cap, Martagon Lily or *Lilium Martagon* grows wild in Siberia and Europe. The different varieties present different coloring. The roots, it is said, are eaten by the Cossacks.

The Bulb-bearing Lily, or *Lilium Bulbeiferum*, grows in the Alps and is cultivated by gardeners everywhere. It has large, red, showy flowers, and bears bulbs in the axils of the upper leaves.

The White Lily, Madonna Lily, Annunciation Lily, or *Lilium candium*, grows wild along the north of the Mediterranean.

The Lance-leaved Lily or *Lilium Lancifolium* bears white flowers spotted with pink, and lance shaped leaves. It comes from Japan and Corea.

The Giant Lily or *Lilium Gigantium* grows wild in the Himalayas. It is the largest of all the Lilies.

The Tiger Lily or *Lilium Tigrinum* is another spotted variety, very well-known. It comes from China.

The Calla-lily of the household is not a Lily, but a member of the Araceous plants or Water-Arum family found growing near ponds, and in marshes. It has some of the features of the Lily family but belongs to the genus *Calla Richardia* or *Calla Zantedeschia*.

LOBELIA

An exogenous plant of the natural order *Lobeliaceæ*, which contains almost 400 species. These plants flourish in damp woods in America and northern India. The plant is poisonous. One of the species goes by the common name of Indian tobacco. It is the commonest of the wild sorts, *Lobelia inflata*, so named from the inflated or swollen appearance of the seed-vessels.

LOTUS

The *Loteæ* number over 100 species and include a number of plants of the Water-lily family. The name is very loosely applied. The common Lotus of the United States, sometimes called the Chinquapin, is a beautiful water-plant, with large leaves, flowers, and roots. The flowers are red, pink, and white. The flower is associated with mythology and legend. The lotus-eaters or Lotophagi, of Greek legend, were the followers of Ulysses who ate of the root and forgot their home and friends and were unwilling to leave the land in which they then were. The word has come to mean one who leads a listless, dreamy, irresponsible life, or an indolent voluptuary.

MARJORAM

The genus *Origanum* of the order *Labiatæ* includes several forms of Marjoram. Among these are Sweet Marjoram and Pot Marjoram. These are aromatic, fragrant plants, much used in cooking as a pot-herb. The leaves are entire and the flowers grow in large spikes. The Oil of Marjoram, or Oil of Thyme, as it is often called, is obtained by distillation. Oil of Origanum is the same substance.

MARSHMALLOW

The Marshmallow (*Althæa Officinalis*) abounds, as its name signifies, in marshy places. It is a perennial, growing about 2 to 5 feet high, bearing a cream-colored flower. Its root is shaped like that of a carrot and is much used in the manufacture of confections, as it contains starch and sugar.

MANDRAKE

The Mandrake or *Mandragora*, is a plant with fleshy, forked root, lanceolate leaves, which hide pale-violet or purplish flowers. The fruit is a fleshy, orange-colored berry. The root yields a narcotic poison, not much esteemed now as a medicine. The name alludes to a fancied resemblance of the root to a human form. This also gave rise to the superstitious belief that the plant shrieks when pulled from the ground.

MILKWEED

This group of plants belong to the genus *Asclepias*. They are characterized by a milky juice and have long silky hairs attached to the seed which fill a large pod. They are sometimes called silk-weed. Paper is made from the fibers of the inner bark or bast of some species. Though some are ornamental, the majority of the species are troublesome weeds.

MINT

The Mints or *Mentha* belong to the *Labiatæ*, and are a class of plants having a peculiar lip-shaped corolla, a square stem, flowers mostly in whorls or circles around the stem, and bearing an aromatic juice.

The most familiar is Peppermint or *Mentha piperita*. It is a native of Europe and is both cultivated and wild in America. It bears a volatile oil,—the oil of peppermint, which is used in medicine as a carminative. It is also used for flavoring confectionery, especially the peppermint lozenge.

Spearmint or *Mentha viridis* is often called Garden-mint and is used in medicine and in cooking. Bergamot-mint or *Mentha aquatica* affords an oil used by perfumers.

Water-mint or Horse-mint, *Mentha sylvestris*, and Corn-mint or *Mentha arvensis* are common varieties.

Pennyroyal or Flea-mint is *Mentha pulgerium.* It is much branched and has a weak stem which lies along the ground. It was formerly supposed to possess active medicinal properties but is used now only for the aromatic oil.

Wild Mint is *Mentha Canadensis.*

MORNING GLORY

The Morning Glory is a plant of the order *Convolvulaceæ* that is much cultivated for its attractive flowers which are borne on twining stems. The flowers are funnel-shaped and are of many colors. They are most attractive in the morning, hence the name. A close relative of these is the dodder, which is a parasite and may be seen growing wound around other plants, living upon them, into the bark of which they insert their roots. The Dodder has no leaves and the stems are yellowish in color. The small flowers bear a close resemblance in shape to those of the Morning Glory.

MUSTARD

A yellow flowering plant of the genus *Brassica*, valued chiefly for its seeds. The pulverized seeds are made into a paste which is popularly used as a condiment. In medicine mustard is used as a counterirritant in the form of a plaster or poultice.

NARCISSUS

This genus of plants belongs to the order *Amaryllidaceæ.* They are monocotyledonous and exogenous plants. They have a peculiar addition in the center of the corolla, known as the crown or corona. It is all of one piece in this group. The plants grow from a bulb, the leaves are like reeds or rushes, and the flowers are bell-shaped. They include Daffodils or Asphodels, which have solitary nodding flowers of a rich, primrose yellow. The corona or crown is longer than the tube of the corolla. They are the *Narcissus Pseudonarcissus.* Jonquils represent the *N. jonquilla.* The stems are very rush-like and the leaves are small and almost cylindrical. The flowers are from 2 to 5 in number and are pale-yellow and fragrant. The White Narcissus and Polyanthus Narcissus are much admired. The flowers of all have a delightful odor and furnish a valuable oil to the perfumer.

NASTURTIUM

The Nasturtiums are members of the *Cruciferæ* or Mustard family. Among them are included the Water-cresses. The leaves are usually pinnate, the flowers yellow or white, and small. The seeds are borne in pods. The Garden Nasturtium is cultivated as a climbing plant.

The Nasturtium of the garden belongs to the Geranium family and to the genus *Tropæolum.* Its flowers vary from orange to scarlet or crimson. Its fruit is pickled as capers are, and the leaves and flowers are often used as salad. It goes also by the name of Indian Cress.

NETTLE

The Nettle belongs to the genus *Urtica*, a group of plants without petals, having opposite leaves and provided with stinging hairs. The flowers are greenish and insignificant. *Urtica dioica* is the common stinging Nettle of America. The hairs upon the stem are provided at the outer end with a disk and communicate at the inner end with small sacs containing a poisonous juice. When touched the disk end of the hair is broken off leaving a sharp point upon the hair. This makes a wound or puncture in the flesh, into which the poisonous fluid from the sac runs and irritates it. When grasped firmly the pressure breaks the hairs down flat and no wound results. Some plants furnish a useful fiber.

NIGHTSHADE

The common name of the genus of plants known to botanists under the name of *Solanum.* The flowers strongly resemble those of the potato. It also passes under the names of bittersweet and *Dulcamara*, because the taste is at first sweet and then bitter. It has medicinal uses especially as an anticatarrhal remedy. There is another plant, the Deadly Nightshade, the *Atropa Belladonna*, with which this is often confounded. The latter is highly poisonous and yields atropin.

OLEANDER

The Oleander or *Nerium Oleander* is a plant of Asiatic origin, much cultivated as a house-plant on account of its beautiful rose-pink flowers. It is also called the Rose Bay and the Rose Laurel. The leaves are long and leathery. It grows to a height of from 8 to 10 feet. The flowers and leaves are poisonous. It is propagated by cuttings and is easily reared.

ONION

The Onion, *Allium Cepa*, is a member of the Lily family. It bears tubular leaves which spring from a bulb. It is a biennial, bearing fruit in the second year. It has a strong acrid odor and taste which are due to a volatile oil that is dissipated by boiling. The largest onions are produced in Italy, Spain, California, Mexico and the Bermudas. Garlic belongs to the same family. It has a more pungent odor and taste. Its root consists of 8 or 10 bulbs each of which is called a clove.

PAPYRUS

A genus of plants of the natural order *Cyperaceæ* of which there are seven species. It grows eight to ten feet high and has a strong, woody aromatic root, with long keel-shaped leaves. Up to the 12th century, papyrus, after passing through an elementary process of manufacture, was used for the making of books but after that period was superseded by parchment.

PEANUT

The Common Peanut, or *Arachis*, is a leguminous plant, native to Brazil. The flowers are yellow and do not produce fruit in the air; but the stem of the flower bends downward and pushes the pod of the ovary into the ground and the fruit, in the form of the peanut, ripens and matures some distance below the surface. They are now grown extensively in all warm countries. An oil is extracted from the nut which goes by the general name of Nut-oil and is used as an adulterant of Olive-oil, and as an ingredient of soap. They are largely grown in Virginia, the Carolinas and other southern states.

PEONY

THE Peony, or *Pasonia*, is a large showy flower of the Crowfoot family. The flowers are usually solitary, red, and large. The Siberian is a double white; the Swiss is double crimson or white; the Russian bears fern-like leaves. It has long been a garden ornament and is still prized by the older generations.

PETUNIA

THE Petunia is a genus of plants of the order of *Salpiglossidæ*, native to South America. The flower has a long funnel-shaped corolla, and is white, violet, purple or red. The plants are clammy and hairy, and about 15 varieties are known. It has improved much under cultivation.

PHLOX

THE Phlox is a genus of plants much cultivated in gardens. It is of easy growth and the flowers are attractive. It is a native of America and Siberia. The favorite is the *Phlox Drummodii* found in Texas by Drummond in 1835. The flowers are red, purple, white, blue, or violet, and are arranged in a large pyramid-like cluster or cyme.

PINK

THE term Pink is properly limited to the genus *Dianthus* and includes the Clove Pink, *D. Caryophyllus*, from which have originated all of the forms of Carnation. The flowers of the Clove Pink are purplish, but in the Carnation there are numerous colors and forms. Gardeners divide Carnations into three groups: bizarres, flakes, and picotees. In the bizarres the white color of the ground is striped with two colors one of which is much darker than the other. In the flakes there is only one color on the white ground. The picotee has a white or yellow ground, the margin of the petal is marked with red or with one other color. In the old forms of picotee the color was often dotted over the ground-color. The Ring-marked Pink is the Pheasant's-eye Pink.

PLANTAIN

The Plantain or *Plantago* is a common dooryard weed with broad, flat, green leaves, and flowers arranged upon a spike which is in form like a round file. The seeds upon the spikes are fed to caged birds. Various parts of the plants are used medicinally in the form of poultices and infusions. Sometimes a leaf is bruised and bound upon a wound or sore. It has a reputation as a household remedy.

POKEWEED

The Pokeweed or *Phytolacca* is a common roadside weed in America. It has racemes of white or greenish flowers, deep purple berries. It has narcotic properties, and is used in medicine. The young shoots are sometimes eaten as asparagus. In Portugal the red berries of one species are used to impart color to port-wine.

POTATO

One of the most important of cultivated plants; in universal cultivation in all temperate regions of the world. It is a native of the mountainous districts of tropical and subtropical America, probably from Chile to Mexico.

PRICKLY PEAR

The Prickly Pear, Indian Fig, or *Opuntia*, is found in America in the barren grounds of the eastern shore, and in the valley of the Mississippi. Other varieties are natives of Europe around the Mediterranean. The plant is somewhat bushy, and is sometimes used as a hedge-plant. The fruit is rather pear-shaped and is covered with spines. It is about an inch long and is juicy, with a sweetish acid taste. It is largely used for food and many of the finer varieties have been imported. The name is sometimes loosely applied to a species of Cactus.

PRIMROSE

The Primrose or *Primula* bears flowers of several colors, borne upon stalks which spring from an underground stem. The leaves are wrinkled and the roots live over from year to year. They are among the earliest-flowering plants and are great favorites.

Among the varieties are the Common Primrose, the Cowslip-Primrose, the Oxlip-Primrose and the Polyanthus. The European species are mountain dwellers. Only five species are native to America.

PRIVET

THE Privet or *Ligustrum* is a small shrub much used as a hedge-plant. It is a native of Europe, but imported to America. Some of the species are evergreen. The flowers are small, white, and fragrant. The round berry is usually black. They yield a dye and furnish food for birds. The wood is used for shoe-pegs and for turned designs.

PUMPKIN, SQUASH AND MELON

THE Pumpkin or *Cucurbita Pepo* is a long trailing vine, with heart-shaped prickly leaves of large size. The flowers are yellow and the stalks are hollow. The fruit is a gourd of a deep yellow color containing a stringy pulp containing the seeds. The fruit is used for food, usually as a pie. It is also fed to cattle. The usual method of growth is by planting among corn. *Cucurbita Maxima* furnishes the large, winter Squash. The fruit of this species has been known to weigh two hundred and forty pounds. Other winter Squashes are crook-necked, egg-shaped, pointed, and turbaned, the Boston Marrow and the Hubbard. Winter Squashes are so-called, because they keep well during the winter. The Summer Squashes are smaller in size and are borne upon shorter vines. They are of a variety of colors. In England the vegetable Marrow is the favorite. It is oblong in shape. Melons are similar plants of the genus *Cucumis Melo*. It has a variety of forms. The general name Muskmelon is given to the class. The Cantaloup is named from Cantalupo in Italy where it was first grown in Europe. It is a form of muskmelon, ribbed, pale green or yellow and very delicate. It is much eaten in a raw state. The Watermelon is the *Citrullus Vulgaris*. Like the other melons, it is supposed to be of Asiatic origin. It is from one and one-half to two feet long, smooth and mottled green and white. The edible portion of the fruit is rose whitish, and the seeds are black. The fruit has an abundant, rich, refreshing juice.

RADISH

The Radish or *Raphanus* is cultivated for its edible root, which has an agreeable, pungent taste. The root varies in size and color. The smaller varieties are more esteemed, as being crisper and less woody than the larger forms. The ground will yield several crops a year. They mature in usually about six weeks and require much watering. The pods are sometimes pickled as a substitute for capers.

RANUNCULACEÆ

An order of plants including the common buttercup, of which there are two varieties *ranunculus acris* and *ranunculus bulbosus*. They are distinguished by finely divided, or dissected, leaves and an acrid juice. The flowers are solitary and arranged in loose cymes; they consist of a calyx of five or six sepals and a corolla of five or six petals, with numerous stamens, of a hypogynous arrangement. The bitterness of the plant is due to a volatile oil which dissipates on drying in the process of hay-making; and this accounts for the fact that clusters of buttercups may be seen standing in pastures, untouched by cattle, but they are eaten readily when mixed with hay. The name is derived from the Latin word meaning "a little frog," as many of the species are found on marshes where frogs abound. It is also called the Crow-foot family from the resemblance of the leaves in their finely divided state to the outspread toes of a crow. Many of the species are alpine in their habitat.

RHUBARB

The Rhubarb, or *Rheum* is a well-known herb, sometimes called the Pie-plant. It belongs to the natural order *Polygonaceæ*. The root-stocks are thick and woody, and that of the Turkey Rhubarb furnishes the root used as a mild cathartic and purgative. The leaf-stalks are half-round and grooved. They contain an acid juice. The leaves are large and wavy. The flowers are small, white or green, and form racemes.

ROSEMARY

A genus of plants of the natural order *Labiatæ*, almost allied to sage. The leaves have a short gray down beneath, a camphor-like odor, and a pungent aromatic taste.

SAGE

A GENUS of plants of the natural order *Labiatæ;* there are many species of it. The sage commonly known is a half shrubby plant, attaining a height of about two feet. It has ovate-oblong or lanceolate, finely-notched leaves, of a whitish-gray color, and racemes of purplish-blue. The odor is strong and penetrating and the taste bitter. The oil of the plant is sometimes used in liniments; the leaves are used for culinary purposes.

SARSAPARILLA

SEVERAL species of Smilax grown in tropical America pass by this name. The root of the plants is used as an alterative in medicine, especially as a blood purifier. The name is given to a great many wild-flowers of America which do not belong to the species.

SASSAFRAS

A GENUS of trees or shrubs of the natural order *Lauraceæ.* The wood is coarse of fiber and light, has a strong odor, and a somewhat bitter taste.

SENSITIVE-PLANT

THE *Mimosa pudica* of the conservatories shows such peculiar action under a touch that it is known as the Sensitive Plant. The leaves are pinnately compound, with very small leaflets arranged on both sides of the stalk. Each of the little line-shaped leaves curl down at night and the leaflets touch each other. They expand in the light again. But during the day the slightest touch will cause them to assume the curled position. The flowers are purple and are grouped in heads. Other plants betray similar irritability but in a much less degree.

STRYCHNIA

A POISONOUS vegetable alkaloid, derived from the seeds of the *strychnos ignatia* and *nux-vomica.* Discovered in 1818 by Pelletier and Caventou.

SUNFLOWER

The Sunflower or *Helianthus* is noted for its bright golden flower-heads. It is grown for ornament and food for poultry. There are many forms of the plant, both wild and cultivated. Some wild varieties are only a few inches high, while many cultivated forms reach a height of from 10 to 12 feet. The flowers yield an oil known as Sunflower-oil and it is used as a drying oil. The oily seeds have some repute as a cure for heaves in horses.

SWEET POTATO

The Sweet Potato or *Ipomœa* is a plant of the same family as the Morning Glory. It is a creeping vine, with heart-shaped or triangular leaves. The flower is very like that of the Morning Glory, and is rose-purple with white border. The roots are very rich in starch and sugar and form an important article of food. A large form of Sweet Potato is called in the Southern States a Yam, but it is not the true Yam.

TEA, THE CULTIVATION OF

Among the many lands where the climate and soil are especially adapted for tea-culture, are China, Japan, and India. In our own country the plant can, with extreme care, be raised as far north as the District of Columbia, but farther south, in South Carolina, and Georgia, it flourishes abundantly.

Tea is best grown upon the slope of a hill, but almost any good, arable soil, free from stagnant moisture, is suitable for the cultivation of the plant.

In China, the tea-plant blooms in November, and the seeds are ready by the next autumn; they are kept in sand until the following spring, and are then sown in beds for transplanting, or in rows, where the full-grown plants are to stand.

The tea-plants are set from four to five feet apart, each way. When they are eighteen inches in height, the leading shoots are pinched from the stems, in order that a more luxuriant growth of leaves may result. In the third year of the shrub's growth, there is a small picking of leaves taken from it, but the maximum yield is not obtained until the tenth year, after which the plant declines in vigor.

Tea-plants are generally kept down, by trimming, to five feet in height. At the start, they require much fertilizing.

The quality of tea depends largely upon the time of the gathering. The younger and more delicate the leaf, the finer the tea; but the first picking is comparatively small. It takes place about the first of April and consists of the buds and youngest leaves. The more important crop is secured in May. In July, an inferior crop is gathered.

The tea picker carries a basket, hung by a cord around his neck, so that his hands are free for the work of gathering.

After picking, the leaves are treated to prevent fermentation. As the first step in this process, they are exposed in shallow baskets to the sun and air, which withers them slightly. Afterward they are placed in pans heated by charcoal, and stirred rapidly; they are then rolled by hand into the required shape.

The black and the green teas are principally grown in China. There are several varieties of each. To-day, the scented teas are much in demand. They are produced by mixing flowers with the tea and allowing the mixture to stand for a time.

The flowers are then sifted out, but their fragrance has been imparted to the tea. This process, however, is not common in the preparation of choice teas, but is confined rather to the inferior brands.

There are numerous adulterations practised in making teas ready for market; fine teas being mixed with those of an inferior brand, and even with rice and dust. Adulterations may be detected by straightening out a tea-leaf after it has been boiled, and examining it with the aid of a microscope. In this way the presence of foreign substances may be readily detected.

TOBACCO

Tobacco, the common name of several species of the genus *Nicotiana* is a narcotic plant native to America, Australia, and the Pacific Islands. It is said that Jean Nicot, when French ambassador to Portugal, sent the first plant to Catherine de' Medicis; hence the name. It is usually an herbaceous plant with white, yellow, green or purple flowers. The common species is *Nicotiana Tobacum.* It grows from 3 to 6 feet high, and some of the lower leaves are very large. Maryland tobacco is the variety *macrophylla*, or small leaf. The Virginia is the *angustifolia* or narrow leaf. The Indians raise the *quadrivalvis.* The production of tobacco in the United States is the greatest in the world. The Cuban or Manila tobaccos are of fine quality. Turkish and Latakian tobaccos are considered

very fine. The leaves are cut and dried in sheds for several weeks. The leaves are then stripped and sorted and allowed to remain in little piles to slightly ferment.

TOMATO

The Tomato, *Lycopersicum esculentium*, is a native of South America. The stem is weak and in cultivation requires a support or trellis. The leaves are interruptedly pinnate, the flower is small and yellow, and the fruit is usually roundish and filled with small seeds in a watery juice. The names are given according to the shape of the fruit: pear, cherry, currant, grape, and strawberry. The color of the large varieties is red, but some of the others are yellow. It is used as an article of food, as a salad, and boiled or preserved.

TURNIP

The Turnip, *Brassica Rapa*, is a common vegetable introduced from Europe. The Rutabaga or Swedish turnip is a long-rooted variety with smooth leaves. There is not much nutrition in turnips as they contain over 90 per cent of water. There are many varieties of the plant which are used as food and as fodder for cattle. Though in the case of milch-cows too severe a diet of turnips is liable to taint the milk.

WOOD-SORREL

The popular name of species of *Oxalis*, a genus of plants belonging to the Geranium family. Characterized by a thin, sour juice, leaves of three obcordate leaflets, and regular flowers of different colors.

YAM

A genus of plants of the natural order *Dioscoreaceæ*. The species are found mostly in tropical countries; they have tuberous roots and herbaceous twining stems. The roots of some species are valued as a food article.

YARROW, OR MILFOIL

A weed belonging to the family *Compositæ*, allied to wormwood, tansy, and chamomile, found in the United States and Europe.

FERNS

The Fern is a plant whose leaf consists of delicate, lace-like radiations which, in the species called Tree Fern, often reach from twenty-five to thirty feet in length. In some varieties, the plants are less than one inch in height.

If one search for Ferns early in March, a small evergreen variety may be discovered. In April, the woolly croziers, of fiddleheads, appear, and quickly develop into the luxuriant plant found on low, wet ground and along roadsides. Early in May, the Osmundas reach a goodly state of development, and the Royal Fern is to be found, delicate and fleshy, in wet meadows. The Interrupted, or Cinnamon Fern, grows in the open wood or along roadsides. These three plants soon reach maturity, and correspond to one another in size and in the appearance of their flower-like fruit clusters.

The fragile Bladder Fern is to be searched for on rocky banks, and among the spreading roots of forest trees. It unrolls its little fronds, on which the fruit dots appear, early in the spring. Several of the Rock Spleenworts are evergreen. They are sensitive to cold weather, however, and the plant is seldom encountered in winter walks in the woodland. A number of the Shield Ferns endure until spring. Even in the middle of January, the keen-eyed Fern hunter may hope to make some discoveries as to the haunts and habits of his favorites.

In the cultivation of Ferns, a compost of peat, or bog earth, with decayed leaf-mold, yellow loam and silver sand, in equal proportions, should be used when the Ferns are potted. All must be well underdrained. Fragments of mortar and limestone in the pot will prove dangerous to growth.

Collections of the various species of Ferns were practically commenced in 1628, when Mr. John Tradescent returned to England from a trip to Virginia, taking with him many new kinds of Ferns. Rear-Admiral Bligh carried home from the West Indies, where he had sailed in the interest of bread-fruit culture, thirty-seven species of the Fern. In 1813 one half of the known Ferns were growing in the West Indies and in North America.

Some of the most magnificent Ferns of the world grow in the numerous isles of the Pacific Ocean. The island of Mauritius has produced two hundred and thirty-five native species; Java claims four hundred and sixty; Brazil, three hundred and eighty-seven; and the Isthmus of Panama, one hundred and seventeen. Compared with

these results in warm climates, there appear annually within the borders of the arctic zone twenty-six species of Ferns.

The general character of the Fern is much the same all over the world. Members of the species, distinct from the Tree Fern, grow to a height of from one inch to six or seven feet. Some of these varieties are stout and fleshy, others are delicate and filmy, but nearly all are herbaceous, resembling in the nature of their foliage the ordinary flowering plants.

In structure, the plants vary greatly. Some have fronds rising from different points on the root stalk; others are tufted — as, for instance, the Ostrich Fern — while some grow in crowns, with fronds continually rising from the older ones. One of the most interesting species of Fern is the Aquatic, the sterile fronds of which float about in the shallow waters of southern Florida; and there are a few species that are epiphytic. In tropical countries Ferns have been found growing on trees at a height of two hundred feet.

Still another species of the Fern family varies as to the size of its fronds, according to the character of climate and soil. The Lady Fern, which in ordinary localities grows from two to four feet high, has, in mountainous regions, only reached a height of a few inches. In the Northern States of this country, some specimens are produced in May, others as late as September.

In flowering Ferns, the Osmunda includes some of the largest and coarsest specimens. In rich woods, somewhat moist, may be found a few Spleenworts, most of the Shield Ferns, the Beech, Grape, Maidenhair and others. In such situations are found the finest development of Fern foliage. On dry cliffs, the Woodsia species may be looked for, also the Cloak Ferns, Lip Ferns, and Cliff Brakes. Many of these are leathery in texture, while others are thickly covered with tangled hair or scales.

It would be somewhat in the nature of a surprise for a resident of the continental portion of the United States to receive an invitation, when on a visit to a fellow-citizen in the newly-acquired Hawaiian territory, to a feast of roasted Ferns. It is a fact, however, that the Ferns of those islands are cooked, and found palatable, if rather leathery; without salt, they are tasteless.

In past times, the stems of the Fern Tree were sometimes cooked in the steaming cracks of volcanoes. The bases of the petioles of another species have been cooked and eaten in times when there was a scarcity of other food. When raw, these have an odor like that of raw potatoes.

GRASSES

More than 1,300 species of grass have been discovered in North America, and of this number a large proportion is found growing in the United States; 400 or more species are noticed in the Southern States alone. When we recall the vast forage interests of the country, the subject of the growth of the various grasses is pertinent. Each summer, 70,000,000 tons of hay are cut and cured, and this crop is taken from 50,000,000 acres of land. The annual crop is valued at $600,000,000. During the past twenty years great progress has been made in the production of new forage plants, and in improved methods of feeding.

One of the most valuable of grasses is the blue grass of Kentucky, which is most excellent for pasturage and for hay. It is distributed from Maine to the Gulf, and westward to the Pacific, and to Alaska. Nevada blue grass is a fine variety occurring in the Rocky Mountain regions of Montana, and Colorado. Sand blue grass (*Poa leckonbyi*) is a newly discovered species of eastern Washington that grows in almost pure sand, under conditions where well-known eastern grasses would fail entirely.

The lyme grasses present a number of varieties of especial interest. In some sections, Canadian lyme promises to be a most productive hay grass. Woodland lime grass (*Elymusglaucus*) is a common grass of Montana, Washington, and Oregon. Giant lyme grass (*Elymusconsatus*) is a tall rank-growing species peculiar to the region extending from the Pacific slope eastward to Montana. It is one of the dry-land grasses that may prove of considerable value for hay, or for grazing, in the dryer regions of the Northwest. Yellow lyme grass, and small sand lyme grass, are species of Oregon and Washington, which are excellent natural sand binders. There are large areas of this country bordering on the Atlantic and the Pacific coasts, the shores of the Great Lakes, and, frequently, on the banks of rivers, which are covered with shifting sands. In some cases, the shifting of these sands proves a serious menace to profitable agriculture, and often a danger to navigation. A few grasses have been found which may be utilized in effectually binding these shifting and destructive sands. Along the Columbia River, the spontaneous growth of the sand lyme grass has in many cases effectually checked the drifting of the sands which are blown out from the river bed.

The wheat grasses are characteristic grasses of the Northwest. Western wheat grass (*Agropyron spicatum*), known to many of the ranchers as bluestem, is one of the best of native grasses for hay.

Meadow wheat grass, a closely allied species, is also a promising variety. Bunch wheat grass (*Agropyrum divergens*) may be classed as first among the dry-land species. It grows naturally in exceedingly dry soils, and in localities where the annual rainfall is light. This wheat grass and the two feather grasses (*Stipa viridula* and *Stipa comata*), common to the same region, are the most promising species for regrassing the overstocked ranges.

Blue grama (*Bouteloua oligostachya*), known also in some regions of Montana as buffalo grass, is one of the pasture grasses. It is readily propagated from seed and thrives in almost any soil. Side-oats (*grama*) has a wider natural range, and although making a turf inferior to that of blue grama, it is nevertheless an excellent pasture grass, and under favorable circumstances yields an abundant hay crop.

In the mountain districts grow many native species of fescue. Creeping fescue, and sheep's fescue, exist in numerous varieties, some of them possessing many points of excellence. Aside from these two species there are others of equal value. King's fescue is one of these. It is a native of Colorado and has been successfully propagated from seeds which it yields abundantly. Buffalo bunch-grass covers extensive meadows in Montana; it affords excellent grazing, and is occasionally cut for hay.

With more than 1,000 known species of native grasses growing north of Mexico there are not yet more than a dozen native species under cultivation in this country; nearly all of the species are adaptable to general climates and soils. Many grasses would make beautiful acquisitions to floral gardens. A plant notable for its beauty and stateliness is the sea-side oat, found along the southern Atlantic coast.

The principal lawn-grasses now in use are Kentucky blue grass, creeping bent, and the Rhode Island bent, the first a species of Poa (*Poa pratensis*), the latter belong to the genus Agrostis (*Agrostis stolonifera* and *A. canina*). White or Dutch clover is often sown with Kentucky blue grass. There are also several of the fine-leaved fescues, which are valuable lawn grasses in the regions where the Kentucky blue grass may be grown. Canadian blue grass is a native, and when properly handled makes a beautiful, rich, bluish greensward. It is especially valuable for holding terraces. Crested dog-tail grass is soft and fine-leaved and has been sparingly cultivated in this country.

A rich emerald green is the shade most desirable in a lawn grass, and no grass of the Northern and Middle States meets this requirement as well as does the Kentucky blue grass. Some of the fescues

possess an equally deep shade of green, but the best turf-forming varieties of this class have a grayish tint which is more or less objectionable. Creeping bent and Rhode Island bent are much alike in color, considerably lighter than the Kentucky blue grass but of finer texture. Some of the varieties of fescues have exceedingly narrow, or thread-like leaves, but the turf formed by them may be harsh and unpleasant to the touch.

BARLEY

A name given to both the plant and grain from the genus *Hordeum* of the order of the *Gramineæ* or Grasses. It is used largely as food for animals and in the manufacture of fermented liquors, as beer, ale and porter, and whiskey. It grows over a great extent from Lapland and Iceland to the Andes and Himalayas. As it is cultivated it increases in the number of rows of grains in the head, which are from two to six rows. The six-rowed species is called Winter Barley, the small Barley is four-rowed. When the grain has the outer coatings removed from it and rounded by grinding, it is called Pearl Barley. It is largely used in the making of broths and soups. The yield is from ten to fifty bushels per acre and the product of the United States is annually about 80,000,000 bushels.

CORN

In the United States, we mean by the term Corn maize or Indian corn, a species of the Grass family, which next to rice is perhaps the most important of food plants. In Great Britain, the term is generally applied to such cereals and farinaceous grains as wheat, rye, barley, and oats. The maize plant has been long known in this country, being originally, it is supposed, a native of Mexico, and largely in use by the Aborigines. It forms about two-thirds of all the grains grown in the United States, the average annual yield being over 2,000 million bushels. Its chief use is as a food for cattle, sheep, and hogs, though when coarsely ground it makes hominy and when finely ground cornmeal. Indian corn is, moreover, a large constituent of starch, glucose, and grape sugar, while the leaves and stalks of the plant, when dried, are largely used for cattle fodder. Besides the sweet or sugar corns, there is also the variety in use as pop corn, with its small kernels and ears. Broom corn is Sorghum Dora, while Kaffir corn is a sweetened sorghum, akin, probably, to the Arabian millet or to the Chinese sugar-cane.

FLAX

Although the cultivation of flax is carried on with satisfactory results in western portions of the United States, the best flax is grown on the other side of the Atlantic. The European countries favorable to the growth of the plant are Russia, Great Britain, Ireland and Belgium. In the latter country, through which the river Lys runs, is produced the finest flax in the world.

A moist climate is most favorable to flax raising, and strong, deep loam is the best soil. As a preparation for the planting, the land is plowed in the fall and again in the spring. Then follows a harrowing, and a thorough manuring of the soil. Afterward a liquid manure is spread over the ground; as much as twenty-five hundred gallons to the acre being used. Next comes a light rolling. The seeds are sown in rows, eight or nine feet apart. American cultivators sow about one-half bushel of seed to the acre. They cultivate largely for the seed.

After the sowing, the roller is again used, until the earth becomes compact and hard.

One of the principal cares of flax culture is the weeding. In other countries than our own the women and the children attend to this work, which is one of great importance.

When the leaves of the plants begin to fall, and the stems turn yellow, harvesting should begin. In the United States, the harvesting machine is used and the plants are cut off at the roots. In European countries, the growers are more careful of their product, and take pains to remove the plants from the ground, roots and all. This is probably the better way to harvest, for the flax so gathered has attained a fame for excellence not achieved by the American product, planted, and harvested, as it is, with so much quickness, and dexterity, by machinery.

After the sheaves have been gathered in, the seed is removed by hand, and by machine. Then comes the «retting» or «rotting,» *i. e.*, the loosening of the fiber from the wood. To accomplish this, the sheaves are thrown into vats of water and allowed to remain there until they rot. In Belgium, the flax grown along the river Lys, is rotted either in that river, or in water taken from it. There are chemicals in this water which seem peculiarly to aid in the retting, and flax retted in the Lys readily brings in France a price twenty-five per cent more than the local product.

After the retting, the woody pith is removed from the stalks and a combing process takes place, which results in the elimination of all chaff and short tow.

In European countries one planting of flaxseed is sufficient for the production of crops for eight consecutive years. In America such care is not taken, and frequent replanting becomes necessary.

In several countries, notably in England, the cultivation of flax has been influenced by legislation. The flax raised in Ireland, where hundreds of thousands of acres of it were once under cultivation, is used in the manufacture of the famous Irish-linen.

The American manufacturers are paying to-day one-third more for the best foreign flax than for that grown at home. Although more than $10,000,000 is invested in the industry in this country, more than $15,000,000 worth of foreign product is imported annually. All of which says much for the European soil and climate, and also for the thoroughness of the method adopted by the cultivators.

FOXTAIL GRASS

Foxtail Grass (*Alopecurus*) has a variety of species marked by soft brush-like tufts of flowers. It is found abundantly in meadows and pastures. It ranks from nutritive varieties to troublesome weeds. The chief varieties are: Meadow Foxtail; Slender Foxtail; Water Foxtail; Bristly Foxtail; and Green Foxtail.

HEMP

In both temperate and tropical climes, throughout the world, hemp is cultivated for one purpose—the manufacture of rope, cordage, and cloth. The hemp raised in some countries will grow from year to year, for a dozen or more years, without replanting, while in other places yearly plantings are necessary.

The production of common hemp, grown largely in this country, has been decreased during late years owing to the large importation of what is commercially known as manila hemp, a product of our Philippine possessions. In one recent year, the exportation of this hemp to other countries, where it is mainly marketed, aggregated 100,000 long tons.

Another kind of the plant important in the world's consumption, is the sisal hemp of Yucatan; this has a fiber of yellowish white—straight, smooth, and clean. The sisal is also found growing from the naked coral reefs, along the Florida Keys.

For the cultivation of hemp in Yucatan, the soil is first cleared of palmetto scrub-roots, which are found in quantities averaging 20 cords to the acre. A plantation is then established by setting out either

suckers or pole plants. When the old plant flowers, the stalk or pole is 15 or 20 feet in height. After tulip blossoms appear, the plant begins to wither, and there starts forth from the point of contact with the flower a bud which develops into a tiny plant. This when grown to the length of several inches becomes detached, and falls to the ground. Such pole plants as come in contact with the soil take root, and in a short time are strong enough to transplant. In the Bahamas, these flower stalk plants are largely utilized to establish sisal fields, and with as good results as where the suckers are used.

In the Bahamas, about 600 plants to the acre are set out in rows, eleven by six feet distant from each other. This space enables the laborers working between the rows to avoid the terrible spurs of the hemp, and also prevents the bruising of the plants through the contact caused by the wind. The piercing of the leaves and the bruising or breaking of them, mean discoloration of the hemp. In Yucatan, the planting usually takes place in June, when the plants are from six to eight inches in height. At the end of the first year, small plants appear around the base of the older ones. These are used for propagation. At the end of two years, most of the leaves of the largest plants are two feet, eight inches in length, and the longest leaves are more than three feet in length. When four years old, the leaves average thirty-three inches in length, and increase about six inches each year for the next three years. The thrifty seven-year-old plant has leaves five feet in length. Harvesting has been going on for several years, when the leaves are found of such size. The leaves of the sisal hemp constitute the valuable part of the product—the part from which is made the better quality of rope for the rigging of vessels. In the common hemp of the United States, and in the manila hemp, the stalk, not the leaves, is used for commercial purposes.

Cultivation and harvesting of hemp are carried on in Yucatan at various times of the year. The laborers cut the leaves with sharp machetes. The cutting of two thousand leaves is considered a good day's work. The annual yield for fiber is from one thousand to fourteen hundred pounds to the acre. From fifty to seventy-five pounds are gathered from one thousand leaves. A hemp plantation usually has from five hundred to eighteen thousand acres under cultivation. The common hemp, such as is raised in Kentucky, is a native of India and of Persia, and is grown almost the world over. It is produced principally for the manufacture of linen threads and the rigging of vessels. Italy produces some of the best of this kind of hemp. The plant reaches a height of from six to fifteen feet.

The making of hemp rope for rigging and for other uses, is carried on in almost every part of this country. The Russian hemp

fiber is highly regarded in rope-walks on account of its great strength, derived largely from the process of retting, or rotting, through which it passes. The first step in rope-making is usually the process of hackling, which separates from the general mass of material about 20 per cent of tow and waste. The fiber then passes through the spreading and drawing machines, and is afterward converted by the spinning machine into yarns; each yarn is made up of either twenty or forty strands. Yarns of twenty strands make one strand of a three-inch rope, which is a key for sizing. From the spinner, the yarns are wound over a bobbin which will carry 300 fathoms. If the stock is to be made into manila, or white rope, the fiber is taken to the laying ground. If for rugged use, it is drawn rapidly and in large quantities, through exceedingly hot tar. As the fiber passes onward, metal rollers catch it, and the superfluous tar is pressed out. After leaving the tar-box behind, the yarn moves over a drum which has a cooling action. Then the yarns are drawn together into strands. A strand becomes left-handed as the man forming it works right-handed. In making the strands into ropes, one and one-half turns to the inch of yarn are given. This in done in the «walk.» A man starts at the «former» and works down the walk, working right-handed, twisting the strands. As rope is made, pieces of each kind, six feet long, are cut off and tested. The requirements in a government test are that a six-inch piece shall hold 4,200 pounds and an untarred piece, 3,200 pounds. From five to six pounds are allowed to the fathom. The tarring of the yarns makes the rope less strong but more durable, especially that which is used in a ship's rigging.

Manila rope is made without hackling, and is oiled instead of tarred. In twisting ropes together to make a larger rope, a twist is given at each length, equal to the rope's circumference.

OATS

THE plant or fruit of the *Avena sativa* is the well-known cereal. It grows best in the temperate region, and degenerates as a point north or south of that is taken. In point of nutrition it is said to rank higher than do the Wheats. The Potato-oat has a large full grain and is much esteemed, as is also the Black Poland. On poor soils the Tartarian and Siberian thrive well. In 1902 in the United States 987,842,712 bushels of oats were raised upon 28,653,144 acres of land. They had a farm value of $303,584,852 and averaged $30\frac{7}{10}$ cents per bushel, and a yield of $34\frac{1}{2}$ bushels per acre. The yield value per acre was $10.60.

PAMPAS-GRASS

The Pampas-grass or *Gynerium*, is found abundantly upon the pampas of South America. It has very silky, luxuriant panicles upon stalks of from 6 to 12 feet high. It has a feathery plume-like appearance and when dried is often colored with brilliant dyes as an ornamental grass.

QUAKING GRASS

A genus of grasses (*Briza*) whose value is due to the fact that it thrives on comparatively poor soil.

RICE

Rice, *Oryza sativa*, is an Indian and Australian grass. It is much cultivated in India, China, Malay, Brazil and the southern United States. It is said that Thomas Jefferson procured some grains of Rice in Italy, brought them in his pockets to America and distributed them to the farmers, ten grains to each. It is eaten more than any other single article of food. It is especially suited as food for warm countries as it does not contain much albumen or flesh producing matter. It does contain over 75 per cent of starch. It ranges from 1 to 6 feet in height. The land must be so situated as to be irrigable. When rice is ground it forms rice-flour, much used as food and as a face powder. From the rice-flour a paste is made by boiling; it is known as rice-glue. The straw of the rice is used in making rice-paper. A fermented liquor, called sake, is made by the Japanese from rice.

RYE

Rye, *Secale cereale*, originated in the region around the Black and Caspian Seas. It is a hardy grain, stands cold and does well on light, poor soils, and these will bear a succession of crops. It is extensively grown in northern Europe where it supplants wheat, and provides the black bread of Russia and Germany. Rye cakes in Sweden are made at two bakings a year and kept by drying. It supplies the Kvass of Russia, the gin of Holland and whiskey in the United States. The straw is used for filling horse-collars, mattresses, and for thatching. It is attacked by a fungus growth called ergot, known in pharmacy as *secale cornutum*.

TIMOTHY

Timothy, *Phleum pratense*, is the favorite hay grass of the United States. It is found native in the Eastern Hemisphere and in some parts of the Western. It takes its common name from Timothy Hanson by whom it was taken from New York to North Carolina in 1720. It is very nutritious and is preferred by horses and cattle. It is cut when in flower. Sometimes it is planted with clover, but the two plants ripen at different times.

WHEAT

Wheat, *Triticum sativum*, is a grass indigenous to southwestern Asia, but generally grown all over the world. It is divided into several classes, such as bearded and beardless wheat; spring, summer, and winter wheat; white and red wheat. An analysis of the wheat grain shows that it contains 67 per cent of hydrocarbons, 13 per cent. of albuminoids; and only 14 per cent of water. This makes it the most nutritious of grains. The seeds are ground into flour. The richest properties are contained nearer the outside shell or the kernel. Graham Flour includes nearly the whole grain except the cuticle.

MOSSES

If you wish to find plant-life delighting in the cold, damp days of winter, fearing neither frost nor snow and welcoming mist and rain, you must go into the woods and study the Mosses. As autumn passes away, they begin to cover the woodpaths and to creep over the roots of trees. They suck up the water in the bogs and clothe the damp walls and stones with their soft, green carpet. Doubtless you have often gathered patches of this thick-felted carpet and, when you have pulled it apart, have seen that each leafy stem is separate and can be taken away from the others without breaking. In some dense Mosses, each stem is single and clothed with leaves wrapped closely around it. In others, the stem is branched, and in others still, the leaves grow on side stalks and give them a feathery appearance.

But in every case each stem is like a separate plant and has its own tuft of tender roots. The reason why these independent stems grow in such a dense mass is, partly, because Moss multiplies so rapidly, that new stems are always thrusting themselves up to the

light and, partly, because the stems were not always separate, but in very early life sprang from a common source.

If you go where Moss is growing and look very carefully on the surface of the ground, you will discover a spongy, green mass, below the growing Moss, very much like the green scum on a pond. This tangled mass of green threads is the first growth from which the Moss stem springs. As soon as it has started, it grows and spreads very rapidly. It drinks in water and air through all its tiny cells, and sends up the Moss buds, which swell and grow and give out roots below and fine stems above. The latter become crowded with leaves and form the velvety Moss.

Although each stem has a few hairy roots, they are very feeble and not at all like the roots of other plants. They are not sufficient to gather nourishment. The fact is that the Moss is built up entirely of separate cells, like the green film on the ponds. These cells are not shut in, but each has the power to take in water and gases through its tender skin. Each acts as a separate plant and grows quite independently of the roots below, whose chief use seems to be to hold the plant in position.

This explains why the Mosses grow so fast and so thick, for new growths can start from any part of the plant. They practically make their own soil, since the matted threads decay and form a rich loam. Thus the Mosses, providing their own food, can spread over the poorest soil and clothe walls and roofs with their rich green.

After the Moss has gone on, through the damp winter, spreading and growing, there appear something like tiny flowers at the tops of some of the stems. These flowers are really formed of a few green leaves, shorter and stouter than the rest, and they inclose little sacs of two kinds. The two together form the plant eggs or spores, which answer to the germs in the seeds of higher plants, and from each a new plant may grow.

There are a great many varieties of Moss which differ in the shape and arrangement of their stems and leaves. In the arctic regions, the Mosses live on vast, marshy plains called Tundras, where they flourish during the coldest winter seasons, and appear fresh and green when the snow melts away from above them. The flowers on some of these arctic Mosses, instead of being green, are of the most beautiful colors. What a wise provision of nature that in these cold regions, where few plants can grow, the hardy Mosses supply the need that all people must feel for some of the pleasure that only flowers can give!

The beautiful gray Moss, known as the Spanish Moss or Long Moss, drapes the trees of the southern part of the United States and

From col. Chi. Acad. Sciences.

CACTI.
½ Life-size.

APPLE BLOSSOMS.

Central America. Feathery tufts of this Moss, several feet in length and perhaps eighteen inches through, are attached to the branch of a tree by a single thread-like root. It differs from most of our other Mosses in being of a silvery-gray color. This is the Moss so much used, when dried, for stuffing mattresses and cushions.

In many localities, the nature-lover can more easily make an interesting collection of Mosses than of other plants. He may live many hundred miles from the seashore and have difficulty in obtaining desirable specimens of seaweed, yet few localities are far removed from some beautiful species of Moss.

When gathered, Mosses should be washed clean and laid out on paper to dry. In this dry state, they may be put away in envelopes of cartridge paper, until the collector is ready to identify and arrange his specimens. A portion of the plant to be identified should be placed in water, until it is restored to its natural state. It is easier for the young student of Mosses to identify the species that bear fruit, and later he will learn to know other kinds by their leaves.

THE CACTI

This curious and always interesting order of plants is distinctly American. Widespread throughout North and South America, and the West Indies, there are in the world but two varieties, of a single species, the origin of which has not been traced to the Western Hemisphere. The Cacti in general are known for their succulent, curiously-jointed, often leaf-like stems and almost entire absence of true foliage. A striking characteristic is that they flourish under apparently the most adverse circumstances.

A favorite habitat, in fact, appears to be a hot, arid desert, where the soil would seem to be anything but nourishing; where the air cools suddenly with the going down of the sun; and where the occasional rainfalls are followed by long periods of drought. But the Cactus is possessed of that great virtue, adaptability, for, while even a crevice in the rock will satisfy it, it does not utterly scorn the luxury of a rich soil. There are more than seven hundred well-established species of Cactus, and several of these deserve special mention.

The red or creamy-white flowered plants, with flat leaf-like stems distinctly jointed, belong to the genus *Epiphyllum*. The genus *Cereus* is well known, chiefly on account of the much-prized night-blooming variety. This plant has showy, white flowers, exceedingly fragrant, which open in the evening and close early in the morning. Some of these open but once a year; and it is quite common in small towns

and villages for the owner of such a plant to invite his neighbors in to see the blossom. It is a slender, trailing or creeping plant, native to the West Indies. Much handsomer, however, is the Macdonald Cereus, a gigantic species, the flowers of which measure more than a foot in diameter when fully expanded. These flowers also are white, but last only a few hours. When eight or ten open in one night, as sometimes happens, the plant presents a magnificent spectacle. The original home of this rival of the Victoria Lily is Honduras.

The Torch-thistle, belonging to the same genus as the two preceding species, grows to a height of twenty or thirty feet, having a straight, fluted, cylindrical stem, or, sometimes, polygonal, flattened into four, five, or six sides. In time the stem becomes woody, and is used for house-building and other purposes. It bears a delicious fruit, sweet and juicy, resembling the Indian fig. This and similar varieties are found in abundance from Mexico to Chili.

The Giant Cactus thrives in the hot, arid regions of New Mexico, attaining a height of sixty feet, and a maximum thickness of about two feet. The stems are cylindrical, usually simple, but sometimes branching upward in a manner to give them the appearance of gigantic candelabra. It bears an edible fruit relished by the Indians, who call it « Saguara.» This is about three inches long, oblong in form, green on the outside, with a crimson pulp and many black seeds.

The Old Man Cactus is a native of the district of Real-del-Monte, in Mexico, where the climate is hot. It also has a cylindrical stem, reaching to a height of twenty or thirty feet. Both this and the preceding species find a foothold in the crevices of bare rocks. The entire plant is gray, with curious long, white hairs at the top, whence its name.

The juicy Hedgehog Thistle of Mexico furnishes drink to cattle and mules in the high plains of that country, where water is not always to be had. The animals, especially the mules, break the stems very cleverly with their hoofs, that they may get the juice within. This is used by the Indians, also, who find it cooling, though slimy.

The Barbadoes Gooseberry, of the West Indies, bears an edible fruit used for preserving. An interesting member of this large family is the Mistletoe Cactus, so called because, like that parasite, it prefers to make its home on a tree. The Prickly Pear, or Indian Fig, is another edible fruit of a species of Cactus. It is native to the United States.

LICHENS

WHEN you find the mosses growing in the woods, you will also see the Lichens hanging from the branches of many of the trees, like gray beards. The leafy Lichens encircle the branches and their pale and yellow patches look as if they were made of crumpled paper, cut into wavy plates. The crusty Lichens are scarcely distinguishable from the bark of the trees, and they usually cover every available space which the mosses have left free. They are such strange-looking plants that it is difficult to imagine that they are alive at all They resemble fungi, in the fact that they prey upon all kinds of living matter, but they are different in one very important respect.

Botanists have discovered that the Lichens are really the result of a partnership between single-celled fungi and single-celled green plants. The gray part is from the fungi, but when we examine it under a microscope we find that it is not at all of fungus growth. A number of green cells can be seen scattered through it. Through the fibers of the hairy Lichen, which you so often see upon trees, are the circular rows of these green cells. In the leafy Lichen, which presents only one surface to the sun, while the other is against the tree, there is a single layer of green cells near the surface.

The way the Lichen grows, then, is this. First, a green cell falls on some damp spot and begins to grow. Then comes the spore of a fungus, which first thrusts its tubes into the bark of the tree and then spreads around the green cell. Then the green and the gray go on living together. The fungus uses a part of the food made by the green cell and, in return, gives the latter the advantage of being spread out to the sunlight and of protection from the rough weather. On the whole, the fungus gets the better of the bargain, for while the green cells may live without the fungus, the latter dies without the green cells.

There is hardly any part of the world, except the tropics, where Lichens do not abound. They grow close to the limits of perpetual snow, in the high mountains, and they flourish in the sandy wastes and over the tundras of the arctic regions. A species, known as Reindeer Moss, sometimes reaches a foot in height under the snow. The Reindeer brushes the snow away with his nose to reach this food. In time of scarcity the moss serves as food for the people.

Iceland Moss is another variety of Lichen that forms an article of diet. It flourishes where nothing else can live. Like the mosses, Lichens can be dried up, so that you might suppose them dead, and

yet, because they can absorb nutriment at all points of their surface, when the heat and moisture reach them, each cell drinks in food again and the plant revives. So, when a scorching sun or biting cold kills other plants, the Lichens bide their time, till moisture comes again.

They are great soil makers, everywhere. They break up the tissues of other plants and change their substance into forms fitted for food for higher vegetation. They have, then, their important place in nature, and if they have not the beauties of some plants, they help to make others beautiful.

The little green cells multiply by dividing, as they do in the pond scum, but the fungus forms little pockets, out of which, when they burst, is thrown a very fine powder, whose particles go to form other Lichens. These seeds can only grow, however, where there is considerable moisture. Those which fall in dry places must remain only seeds.

FUNGI

There are many dark and damp places in the world where most plants cannot get enough sunlight or air to make green coloring-matter and manufacture their own food. But there is another class of plants which has found a way of taking in its food ready-made, from other decaying plants and from animals. These plants can live hidden away in dark cellars and damp cupboards, in drains and pipes where no light ever enters, under the thick covering of dead leaves in the woods, and wherever there are decaying substances on which they may feed. Such plants are the molds on cellar walls, the mildew in bread, the smut filling the grains of wheat or ears of corn, the rank toadstools and puffballs you often see in the woods and the mushrooms, some of which are eaten. All these are called Fungi.

They are so widely spread over all things living and dead that there is scarcely anything free from them in one shape or another. Their minute spores float in the air and settle down wherever they find suitable food. Then they feed, fatten, and increase with wonderful rapidity.

Suppose you take, for example, the thin mold you have doubtless seen forming over a cup of delicious jam that had been uncovered for a time. This mold begins with a minute spore or cell from the air. Settling on the surface of the jam, it begins to feed and at the same time to send out very many tubes. Some of these, instead of working down into the jam, reach upward and form at the top tiny balls,

in which are many minute, seed-like bodies or spores. The ball bursts, the spores fall out and are sprinkled over the jam. So little by little, but quite rapidly, the whole surface is covered with a mold which grows thicker and thicker. These molds appear anything but beautiful to the naked eye, but if you have the opportunity to look at them through a microscope, you will be surprised at the delicacy and beauty of their structure.

While these minute Fungi are found everywhere, the larger varieties are confined to the fields and forests, or wherever rotting leaves or wood provide them with nourishment. Few people have any clear idea of the growth of a Mushroom, except that the part we pick springs up in a single night. The real fact is that a whole Mushroom plant is nothing more than a gigantic mold, spreading its tubes underground or through the trunks of decaying trees. The part which we gather and call a Mushroom, a toadstool, or a puffball, is only the part which answers to the little round ball of spores in the mold or mildew. These spring from the underground tubes, from time to time, and at first are egg-shaped, the top half being the larger. Inside this ball are formed a series of folds made of long cells, some of which are to bear spores. As the Mushroom grows, the skin of the ball is stretched more and more till it can stand the strain no longer. Then it breaks away from the stalk, and the ball expands into the shape of an umbrella. All this happens in a single night, and this much you can see for yourself, if you will find a place where it grows and watch its progress. It is in the autumn that you will find these molds most abundant in the woods, and if you study them you will see that they are breaking up, the dead remains of all kinds forming a soft, spongy soil. It is in such rich places that the tender plants of spring will flourish. Thus the Fungi, though they feed upon other life, really help to prepare the soil for the beautiful blossoms of spring and summer.

BACTERIA

A MICROSCOPIC vegetable growth that is actively concerned in the process of putrification and fermentation. They are the lowest forms of vegetable life, and multiply by means of spores. In shape they are spherical, oblong, or cylindrical. They are simply cells without chlorophyll or green coloring-matter. They are extremely abundant everywhere. It is supposed that they take an active part in converting the compounds of nitrogen into proper food for other plants. Their study constitutes Bacteriology, a department of Biology

which studies the life and history of those organisms and the part they play in diseases. A single specimen of some of the species will produce 16 millions in 24 hours. They produce such diseases as Erysipelas, Pneumonia, Measles, Yellow-fever, Meningitis, Typhoid-fever, Diphtheria, Consumption, Lockjaw, and others. The name Bacillus is given to one genus of the Bacteria which are in the shape of small rods. One of this form is known as the "Comma Bacillus," which is a peculiar curved form like that mark of punctuation. It is always present in cases of Asiatic Cholera. Some forms are very useful in breaking up dead decaying matter into water, ammonia, and carbonic acid, which are preferred by plants as food. The cases of poison known as Ptomaine, which sometimes result from eating meat, game, and ice-cream, are due to these organisms which have formed in the article of food. The poisonous effect of Diphtheria is due to the presence of toxin, a name given to the poisons in the membranes which are also due to the presence of Bacteria. It is to counteract this toxin that a substance known as anti-toxin has been prepared, which is injected into the body by a hypodermic syringe and, on much the same principle as vaccination, counteracts the poisonous growth of toxin. It is most efficacious before or just at the beginning of the formation. Bacteria are present everywhere; in the air, water, soil, clothing, teeth, mucous membrane, and on the bodies of men and animals. They are collected for the purpose of study from various sources; one very common way being to expose to the air a mass of gelatine or jelly for a few hours, and then collect the Bacteria from the surface of this and examine them under a microscope. A small portion of the accompanying gelatine may be placed in a small glass test-tube plugged with cotton wool and the Bacteria will increase and multiply in that substance. This method of generation is known as cultivation and the growth so formed is called a colony. By examination of this substance from day to day under the microscope, the development and growth of the Bacteria may be studied. They are very easily collected by soaking dried hay in water and studying the water from time to time, when the organisms may be seen in all their stages of development. The surest means of killing Bacteria is by hot water. The process of pasteurizing milk consists simply in raising it to a temperature of 168° Fahrenheit, when the Bacillus which causes the souring of milk by fermentation is killed. Some forms will stand water at 212°, or the boiling point. Intense cold and freezing seems to have no effect upon them as they easily live through the winter unprotected.

ERGOT

A fungus, *Claviceps*, attacks the ovaries of wheat and other grasses, and produces a diseased condition known as Ergot. As this grows it turns a dark-purplish or velvet color. It is like a mass of horn about one inch long. The danger in eating diseased rye or wheat is very great to both man and beast. It is said to produce a sort of gangrene of the foot in cattle. When present in rye it resembles the spur of a cock, whence the name spurred rye. The tincture of Ergot is used in medicine. It causes a contraction of the coats of the small arteries, and of other organs. In large doses it is fatal.

MILDEW, RUST AND SMUT

Several species of microscopic fungi attack other plants, linen, and other fabrics, and produce the growth known as Mildew. There are Powdery Mildews and Downy Mildews. The Powdery Mildews are produced by a species of fungus known as *Erysipœa*. They attack the common pea, the Composite family and numerous plants. When seen under a microscope they present the appearance of a network of fine thread. They comprise several genera and are usually very destructive to plants. The Downy Mildew is produced by the *Peronosporeæ*. They are among the most destructive of all, and include over 70 species. The Grape-mildew is downy, and appears on the under surface of the leaves. The powdery Grape-mildew attacks the whole upper surface of the leaves. When the Downy Mildew fungus attacks the fruit of the grapes it produces brown-rot. The black-rot is another fungus (*Phoma uvicola*) from the effects of which the grapes shrivel and turn black. Sulphur is the best application for mildew.

Rust is a parasitic fungus growth which attacks cereals, potatoes, etc. Wheat-rust is a reddish growth of a very complex fungus known as *Puccinia Graminis.* This parasite attacks oats and other grains. It usually appears in early spring on the barberry leaves. Later in the season it appears on the leaves and stems of the cereals and as pale-yellow or white spots on the leaves. These change to long orange-red lines which may rapidly include the whole plant. This is the state in which the fungus lives over the winter to begin anew in the spring on the barberry. It is known then as a black-rust. The genus of *Puccinia* numbers over 450 species.

Potato-rot is caused by the *Phytophthora infestans* which was introduced from South Carolina about 1840. It attacks the whole plant. When it attacks the stem and leaves only, it is called potato-blight.

It appears on the leaves as pale yellow-spots. These turn through brown to black, and destroy the whole plant. In the first attacks on the tubers, spots of a dark color appear and these in time involve the whole tuber.

Smut is a fungus which attacks cereals and is extremely destructive. There the black smut produced by the *Ustilagineæ* and the stinking smut or bunt caused by *Tilletia tritici* and *T. fœtans*. The black smut changes the whole head to black dust. The stinking smut attacks the interior of the kernel and can be detected only by opening it. After it appears nothing can be done and whole fields are often destroyed in this way. It can be prevented by soaking wheat seed in a solution of one pound of blue vitrol to a gallon of water before sowing.

Mold is the name given to the vegetable fungus growths which form upon articles of food such as bread and animal and vegetable tissues. They belong chiefly to the genus *Mucor*. They increase chiefly by the formation of spores. The mold appears as a downy, grayish-white growth upon surfaces.

LIVERWORTS

The Liverworts, as a class, are closely allied to the mosses and, indeed, were once classed with them. Their processes of growth are quite similar. But while Liverworts have a leafy stem, they seldom expand into a leaf-like form. They are generally found in such situations as the mosses delight in, and are widely distributed over the globe. The greater number, however, belong to the warmer climates, in which the mosses are less abundant. In such places they grow on the bark, and even on the leaves, of trees.

Our most common species is a small, green, creeping plant, which has a flattened appearance. It consists of a leaf-like stem, about half an inch wide and from two to four inches long. Instead of putting forth little urns, containing spores, it runs up a branch which is the shape of an umbrella, for the slender stalk supports a flat disk. The plant attaches itself firmly to the soil by silk-like roots.

It grows most readily in a moist soil and is common to almost every part of the United States. It is often seen on shaded rocks, walks, or fences. You can readily gather it, with the soil attached to it, and you may carry it home and keep it for any length of time, in a moist chamber, protected from the direct rays of the sun.

There is another species which can always be had at the greenhouses, and can be distinguished from the more common species by

the form of its little cups, the rims of which are broken and shaped something like a crescent. In many of the varieties the spore sacs contain, besides the spore, small green filaments called "elaters." Each consists of two spiral fibers, which remain coiled up together so long as the case is unbroken. But when the case breaks and the pressure is removed, the elaters fly apart and aid in the dispersion of the spores.

ALGÆ

If, when you go to the seashore, you seek a place where the tide runs in and out among the rocks, you will notice clinging to them and to everything that touches the water, masses of green, feathery weeds. They do not appear very inviting, and they are so common and so plentiful along the shore, that you might suppose them unworthy of much attention. But if you will examine them closely, you will be rewarded by finding in these, the very lowest forms of vegetable life, structures of such delicate beauty as you can find nowhere else.

In collecting specimens of seaweed, care should be taken to keep the brown, green, and red species separate. Some species must be carried home in sea water, as their color is changed by contact with the air. As some species change color in fresh water, it is well to wash them in a clean pool before leaving the shore. On reaching home, the specimens should be placed in vessels of clean sea water. In mounting them, place one on a white dish, and if any of the branches stand up so as to be in the way of pressing smoothly, or overlie others too thickly, they should be pruned off with a penknife or with the edge of a porcupine quill.

The specimen should then be placed in a flat dish of very clean sea water, and a piece of strong drawing paper slipped under it. Hold the specimen in place on the paper and with a porcupine quill carefully spread the branches, while they are still under the water, and brush out the feathery tips with a camel's-hair pencil. The paper should be removed from the water gradually, as the sprays are placed in position. If the delicate tips run together, they may be dipped in the water again, just deep enough to float them. The work of spreading should always be done from the center outward. When the seaweed is in the desired position on the paper, the sheet should be laid on a stout, blotting paper and covered with a piece of old muslin. New or starched muslin would stick to the wet seaweed.

In a short time the water will have been sufficiently absorbed, and the sheets may be laid one over another, with blotting paper between.

The pile of sheets should rest on a smooth board and an even weight should be placed over the top. A board, with bricks or irons upon it, will serve this purpose nicely. Within two or three hours, and again in twelve hours the blotting paper should be changed.

You will not need to search the ocean itself to find the really wonderful things which lurk among the green and slimy weeds. It will be better to pick out one little pool lying just above the limits of the low tide, so that it is uncovered only for a very short period each day. It will be convenient to choose a pool not more than two feet across, so that you may step over it, if you take care not to slip on the masses of green and brown seaweed. Lie flat down on the rocks, so that your eyes are free to observe and your hands free to handle.

This little pool is as full of living things as the heavens are full of stars. The tide, as it comes in, brings many a mother cell to find a safe home for her little ones, and many a waif spore to seek shelter from the troublous life of the open ocean. The fine, feathery weeds are the haunts of millions of beings, just as the giant trees of the forest are the haunts of millions of birds and animals.

There are many hundreds of varieties of these seaweeds, and there is a great difference in their size, and forms, but science classifies them all as Algæ. Such plants are not confined to the salt water, but are found in rivers, lakes, marshes and moist places all over the world. Some of them have what you might call roots, but they do not act like the nourishing roots of flowering plants. They simply fix the weeds to the rocks or decaying stumps. The leafy appendages are called fronds, which vary greatly in size, color and firmness. The three leading colors which you will find in the little pool are green, red, and olive or brownish. These tints mark roughly three kinds of weeds, which, however, occur in an endless variety of shape.

You will doubtless find in the pool a pale green seaweed called the Sea Lettuce. It grows in long ribbons in shady nooks in the water. If you should examine it under a microscope, you would see very small cells, with lashes breaking away and swimming off, to start other plants. This plant is merely a collection of cells, and each can work as a separate plant, feeding, growing, and sending out its own young spores.

Another deep olive-green and feathery weed which has a very long, scientific name is of a somewhat higher order of life, and its cells divide their work. Those of the feathery threads make the food, while others, growing on the shafts of the feather, make and send out the young spores.

More lovely still to look upon, are the red, thread-like weeds. One variety carries urns on its stems much like those which may be seen on mosses. The stony corallines are near relatives of the seaweeds, and you will find plenty of them in the little pool. Some of them, of a deep purple color, grow upright in stiff groups about four or five inches high, and others, which form crusts over the stones, are of a pale rose color. Both kinds, when they die, leave pure white skeletons which used to be mistaken for corals.

You will find the little pool full of different forms of these four weeds. The green ribbons float on the surface rooted to the sides of the pool, and the glittering bubbles rising from them show that they are working up food out of the water. The brown weeds lie chiefly under the shelves of the rocks, for they can manage with less sunlight and use the darker rays which pass by the green weeds. The red weeds and corallines, small and delicate in form, line the bottom of the pool in its darkest nooks.

To see the wonderful beauties of their forms, you must try to get one upon a piece of white paper. You cannot do this by dipping your hand in the pool and bringing up the delicate weed between your thumb and finger. If you do this, you will have nothing but a mangled mass of dark stuff. You may place such a shapeless mass on the paper and endeavor to straighten out its many branches, but you will find that you cannot do this. You must catch it as it floats naturally in the water.

Take a small pane of glass and, dipping it in the pool, work it under one of the delicate red weeds. Have your eyes very close to the water, so that you may see as well as possible. When you have a weed over your glass, slowly raise it and, as you bring it near the top, see that the tiny branches of the weed are well spread out, like the branches of a tree. If, when you have it near the top, the weed is tangled, lower the glass and try again, till you bring the weed up in good form. As you cannot see it clearly on the glass, now place a paper over it and turn the glass, so that the weed will leave the glass and adhere to the paper. Then you will behold the wonderful texture of this plant, which is one of the lowest forms of vegetable life.

In mounting seaweeds, they need to be dried, but some must first be carefully washed in fresh water to remove the salty matter. With the delicate forms, this can hardly be done. They must be dried first in the air, and afterward pressed between sheets of drying paper. You will be surprised to find how many varied kinds of beautiful forms you can bring out of that little pool between the rocks.

There are many other wonderful forms of life in it, which you

cannot see with the naked eye, some of the creatures being classed as animals, and some as plants. One of the most wonderful of the latter is called a Diatom. Diatoms are so small, that many of them must be magnified to fifty times their real size before you can even see them distinctly. Yet the skeletons of these almost invisible plants are wrought in patterns of the most delicate designs. Some of them look, when magnified, like a number of rods clinging to one another in a string, but each of them is a single-celled plant. Other forms look more like plants, but all have flinty skeletons running through their jelly-like forms. Each plant leaves its skeleton, and these forms accumulate in the waters of ponds, lakes, rivers, and seas all over the world. Thus, in millions of years, these innumerable microscopic skeletons have formed layers of earth.

It is said that the cities of Richmond, in Virginia, and Berlin, in Germany, are built upon earth composed almost entirely of these minute diatoms, which have accumulated to a depth of even eighty feet. Those under Berlin are fresh-water forms, while those under Richmond belong to the salt water. Every inch of ground under these cities represents millions of living plants, which flourished in ages past, and were all so small that they could not be seen except under a strong magnifying glass.

But there are other Algæ which grow to an enormous size. One long, cord-like seaweed runs out to great length, and masses of it form, in the North Sea and in the British Channel, in beds of twenty miles in length and six hundred feet in width. Other similar varieties form patches on the sea which look like enormous green meadows, and yet ships can readily sail through them. Many specimens of this class have been found to be over seven hundred feet in length. Thus, you will see that the Algæ range from great monsters to such minute plants that you cannot hope to see them without the strongest magnifying glasses.

While many of the seaweeds constitute the food of higher forms of life in the ocean, some forms are also valuable as food for man. None of the seaweeds are known to be poisonous. You may have heard that a dish much relished in China consists of a soup made of birds' nests. You will be right in thinking that none of our ordinary birds' nests would make an agreeable soup, but the nests which the Chinese use are largely made of seaweeds of a certain species, which the swallow known as collocolia, or glue-house swift, collects and fastens together with a glue-like secretion from his own mouth.

One variety growing on the rocks is much used for food in Scotland and Ireland, and is called Dulse. It has an odor something like that of violets and is eaten raw or roasted. It is an important plant

to the Icelanders and, after being washed and dried, is stored in casks to be eaten with fish. Another delicious variety grows on the rocky seacoasts on most parts of Europe, and on the eastern shores of North America. The Irish call it Carrageen, but here it is commonly spoken of as Irish Moss. When properly prepared it makes a delicious dish.

The fresh-water varieties of the Algæ form that soft, green material which is called "pond scum." The color varies according to conditions. When taken in the hand it has a delicate and slippery feeling. There are varieties of these fresh-water Algæ not very unlike seaweeds, though they do not present so many beautiful forms, and are always green. None of the lovely red varieties exist in fresh water.

GULF-WEED

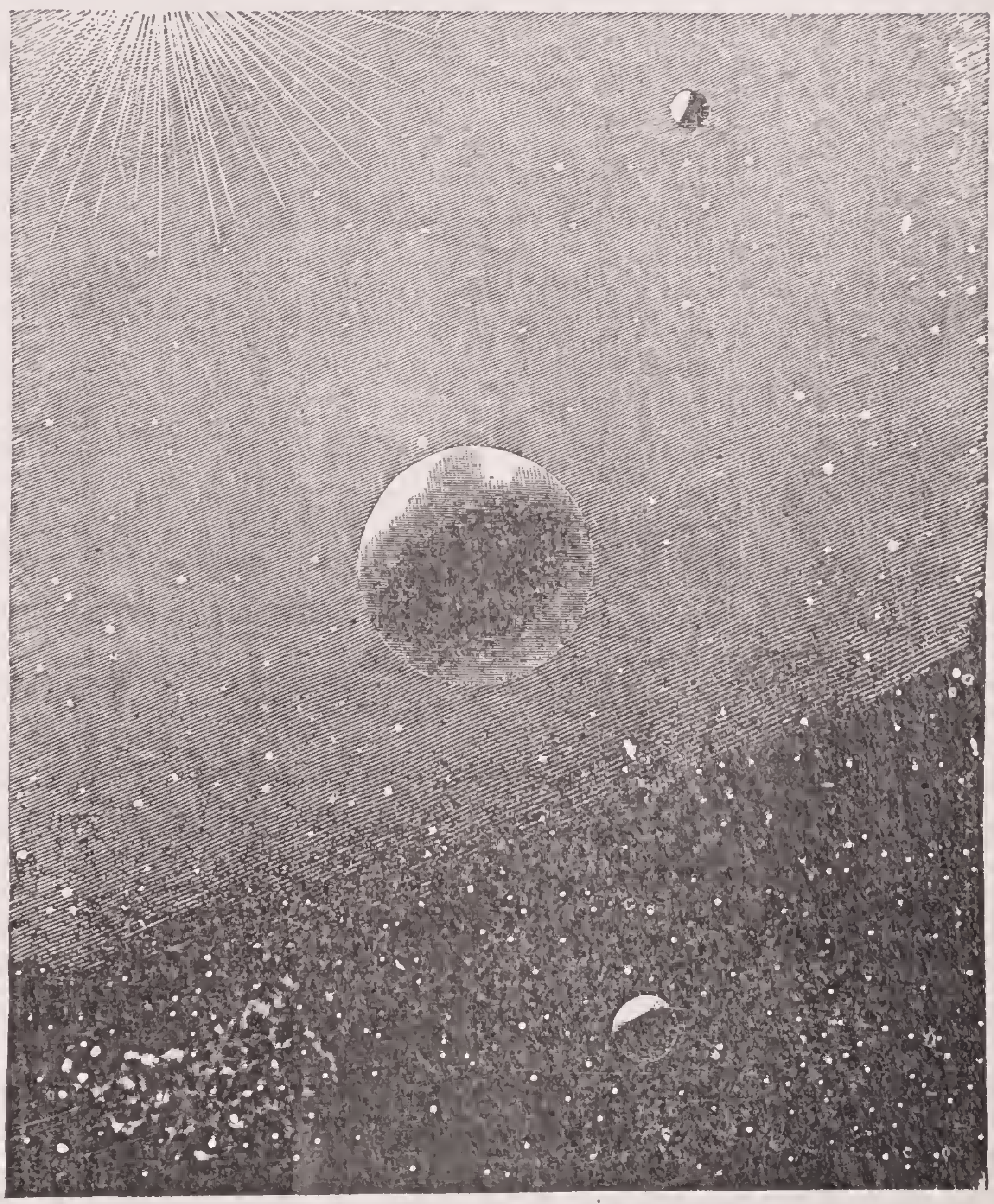
GULF-WEED, or Sargasso as it is called in Spain, is a form of Seaweed, having grape-shaped air-vessels to float it, which abounds in the Atlantic Ocean, and takes its name because it is found on the outer margin of the Gulf-Stream, in N. lat. 20° to 45°. This weed collects in a mass in the ocean in the quiet regions around which the currents of the sea flow; and gathers there as light objects do in the middle of a basin of water when the water is made to revolve. This is known as the Sargasso Sea. It was this that caused the sailors with Columbus such alarm as it was so dense a mass as to almost stop the vessel.

SUN, MOON AND STARS

By PROF. MILTON UPDEGRAFF
Director U. S. Naval Observatory, Washington, D. C.

"TWINKLE, twinkle, little star,
How I wonder what you are!
Up above the world so high,
Like a diamond in the sky."

THIS familiar little nursery rhyme, which we have all heard so many times, expresses a feeling that most of us have often experienced. It is almost impossible for anyone who has not studied the heavenly bodies, to gaze up into the sky on a cloudless night and not to wonder what is the real nature of the little specks that sparkle, like diamonds, against the dark background of the night-sky. No doubt you have asked yourself what they are, how far they are from the earth and what causes them to shine as they do.



Perhaps you have learned that these twinkling Stars are Suns like our own, but there are many other things which you ought to know about them. You ought to know more, too, about our own Sun, which gives us light and heat, and about the pale, beautiful Moon, which at times seems almost to transform night into day.

There are also in the sky other objects, about which you will be deeply interested to learn. There are the planets, which in some ways, resemble the Stars, but which shine with a clear, soft light, instead of twinkling, and which seem to move about among the groups of Stars, instead of occupying fixed positions. Then there are the comets, which look like Stars with long

tails. Sometimes one appears that is of such size and brilliancy as to be the most conspicuous object in the sky as long as it remains visible. Meteors, or "shooting stars," as they are sometimes incorrectly called, are frequently seen, rushing like rockets among the Stars and then suddenly vanishing. These, too, we all ought to know about.

Long before the time of Christopher Columbus, astronomers knew that the earth was a large, round ball, hanging in space, without material support. But the fact that the earth revolves about the Sun once in a year, thus causing the seasons, and rotates on its axis once in twenty-four hours, thus causing the Sun to rise and set, and producing day and night, became known only about three hundred and fifty years ago. Not all the secrets of the heavens have been unfolded, but many things that were once mysteries, have been made plain. In the following pages, you will be told some of the main facts that have been discovered concerning the heavenly bodies, and will so be given a glimpse of the science of Astronomy.

If this science simply taught us the truths about all the wonderful works of nature of which we have spoken, it would be a noble science and well worth our study; for to learn the great truths of the universe will help us to be better and wiser men and women. But Astronomy has other very practical uses, besides simply increasing the sum of human knowledge. For one thing, it helps the sailor. Some of the principal observatories in the world, among them the United States Naval Observatory and the Royal Observatory at Greenwich, were founded for this express reason.

Ships on the ocean, out of sight of land, depend upon the Stars and the Sun to guide them over the trackless waters. Astronomers have accurately calculated the places of the heavenly bodies in the sky, and captains of ships are provided with instruments and charts which enable them to determine the positions of their vessels, whenever the sky is clear. Another use of Astronomy is in finding the size of the earth and in making accurate maps of its surface. Those who carry on this important work depend upon the place of the Stars as a basis for all they do.

THE CELESTIAL SPHERE

THE sky seems to spread over us like a great dome, upon whose inner surface the stars are sprinkled in groups. Some of the stars are very brilliant, others seem mere specks, and still others are so faint and are crowded so closely together, that they appear like far-distant clouds. Wherever we go on the earth's surface we still see the dome-like shape of the sky, as though the earth were surrounded

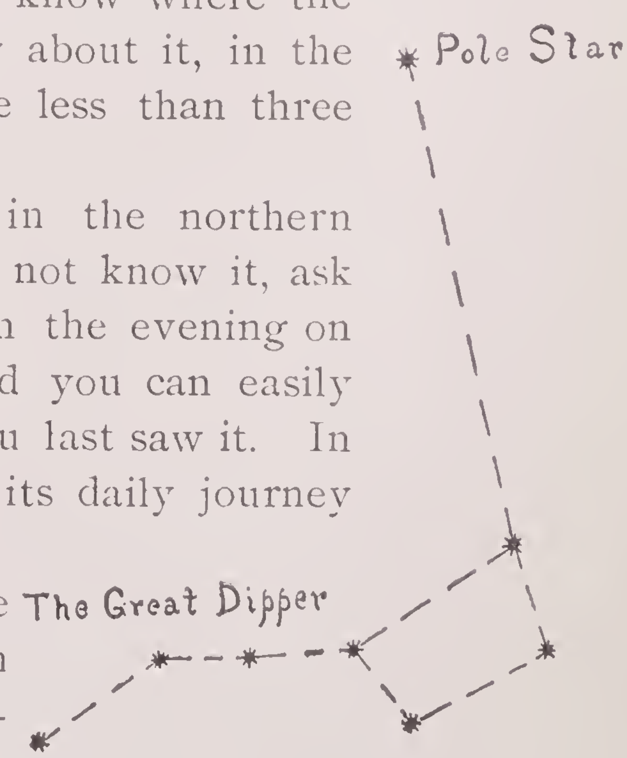
by a great hollow sphere, which, however, we know is apparent, not real. Astronomers speak of the heavens, or sky, as the *Celestial Sphere.*

The stars are really at enormously unequal distances from the earth, but they are all so very far away that they appear to be equidistant from us. To count the stars that we see is not such a hard matter as it appears to be. The number we can really see at one time with the naked eye is not very large, being between two thousand and three thousand. Unless the sky is very free from clouds and haze, we see an even smaller number. If we use an opera glass, many more stars appear, and when great telescopes are used, millions of stars may be seen. With telescopes, too, it is possible to learn many things about the stars and to measure their distance from each other on the Celestial Sphere.

We have all observed the fact that the sun rises and sets each day. In the morning, we see it shining in the east; at noon, it is nearly over our heads; and in the afternoon, it is slowly setting in the western sky. We have noticed, too, that the moon rises and sets, although its times of doing so seem less regular than those of the sun. It may be that some have failed to note the fact that the stars also seem to move from east to west. Not all of them rise and set, for some are always in the sky, and if it were not for the clouds and sunshine we might always see them. But all move in circles about what are called the *poles* of the Celestial Sphere.

A large part of those seen by people living in the United States move in circles about the northern pole. Most of us know where the *pole star* is. It lies near the pole, and moves daily about it, in the sky, in a small circle, the radius of which is a little less than three times the diameter of the moon.

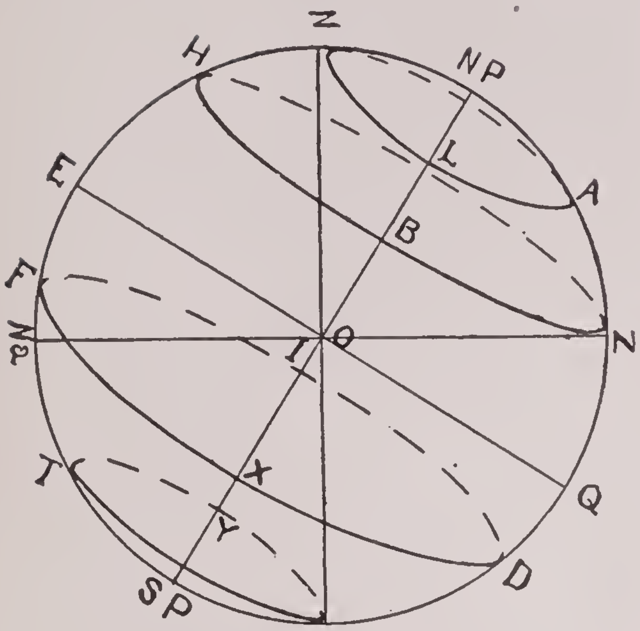
The *Great Dipper* (Fig. I.) is a group of stars in the northern sky with which most of us are familiar. If you do not know it, ask some one to point it out to you. Look at it early in the evening on the next clear night, and again three hours later, and you can easily see that the whole group of stars has moved since you last saw it. In fact, during the three hours it has gone one-eight of its daily journey around the pole.



(Fig. I.)

All stars that are nearer to the pole than the pole is to the horizon, which is the line at which the earth and sky seem to meet, describe their daily circles entirely above the horizon and so never set. (Fig. II.) Stars that are farther from the pole than the pole is from the horizon, describe part of their daily circles above the horizon and part below it; that is to say, they rise and set like the sun. Midway

between the north and south poles of the Celestial Sphere lies the celestial equator, and stars north of it describe their daily circles around the north pole. Stars south of the equator describe their daily circles around the south pole.

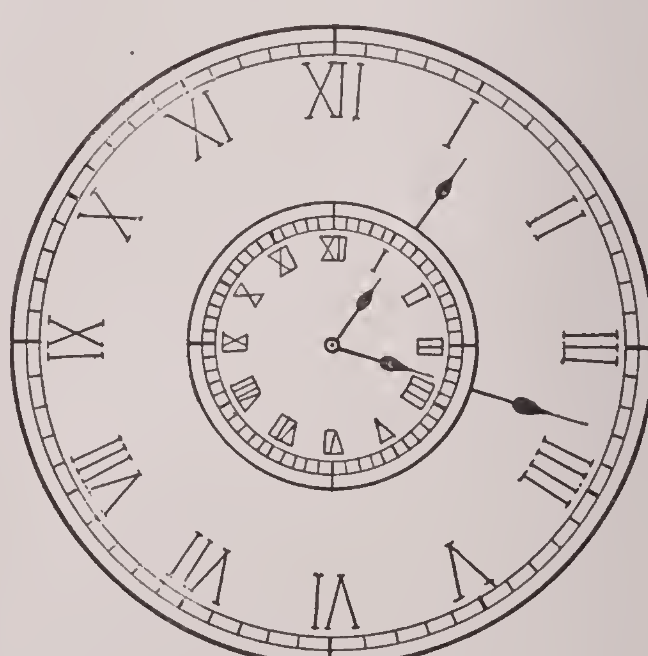


(Fig. II.)

Before going on to learn of the sun, moon and stars, and of their positions in the heavens, it is important that you should understand how angles are measured, for all distances upon the Celestial Sphere are measured as angles.

Every circle, no matter what its size, is divided into three hundred and sixty equal parts, which we call degrees. If the circumference of a circle is divided into degrees, and lines are then drawn from the points of division to the center of the circle, three hundred and sixty equal angles will be formed at the center, each of which will correspond to one of the degrees into which the circumference has been divided. Each of the angles is said to be measured by the part of the circumference which lies between its sides. Consequently, each of the angles formed in the manner just described is said to be an angle of one degree, or 1°. The term Degree is used, therefore, in reference both to angles and to parts of the circumference of circles, or arcs. A degree in the sky is equal to about twice the apparent diameter of the moon. The length of a degree in feet varies with the size of the circle, but the angle that a degree measures is always the same. You may understand this better by thinking of the dials of a watch and a large clock. (See Fig. III.)

Each dial has its circumference divided into sixty parts. The points that separate these parts are much closer together on the watch than on the clock, but each division marks a minute as truly on the watch as on the clock. When the minute hand is at XII and the hour hand is at III, they are separated from each other by an angle which is in each case one-fourth of the circumference of the dial, or by 90°, which is one-fourth of the 360° into which the circle is divided.



(Fig. III.)

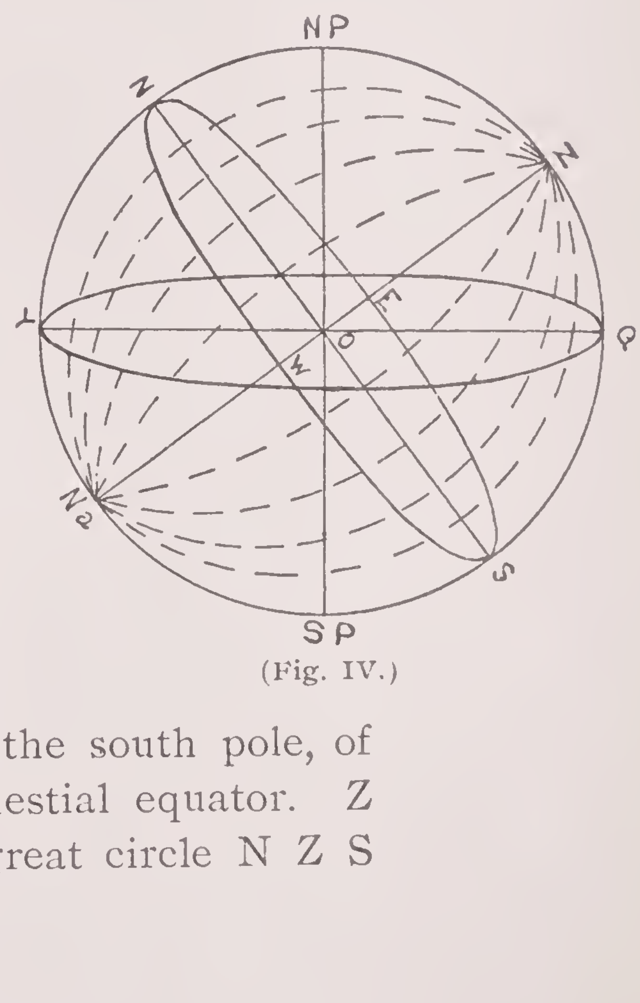
In astronomical measurements we have to deal with circles of all sizes, but usually we are not concerned with miles, feet, etc., but only with angles. If we know that a certain part, or arc, of a circle is one degree in length, and we can measure the length of the degree

in miles, it is plain that we can thus learn the entire length of that circle in miles. This is the principle that is used in determining the size of the earth, and in many other such problems.

There are certain imaginary circles and points on the Celestial Sphere which we should keep firmly fixed in our minds. The *zenith* is the point in the sky directly over the observer's head. The *nadir* is the point on the Celestial Sphere directly under the observer's feet. The nadir is on the opposite side of the earth from the observer, and is, of course, invisible.

The *celestial horizon* is a great circle around the sky, midway between the zenith and the nadir. This is not to be confused with the term *horizon*, as commonly used to designate the line which bounds our view, and which depends in extent upon the height from which we look and the nature of the country about us. At sea the horizon is a circle.

Any number of great circles can be imagined as drawn from the zenith to the nadir. In every one of these circles the zenith and nadir will be separated by half the circle's circumference, or one hundred and eighty degrees. The horizon is everywhere ninety degrees from the zenith and ninety degrees from the nadir. An angle of ninety degrees is called a right angle. The great circles drawn through the zenith and nadir are, therefore, said to cut the horizon at right angles, and are called *vertical* circles. That particular vertical circle which passes through the north and south points of the horizon is called the *meridian*.



(Fig. IV.)

In Fig. IV. the observer is supposed to stand at O. His circular horizon is represented by N E S W, N and S being, respectively, its north and south points. N. P. represents the north pole, and S. P. the south pole, of the Celestial Sphere. Y E Q W represents the celestial equator. Z is the observer's zenith, and Na his nadir. The great circle N Z S Na represents the observer's meridian.

THE EARTH

Among the subjects that interested the early astronomers were the shape of the Earth, and its position and importance with respect to the heavenly bodies. The most common belief was that the Earth was flat and supported by some unknown means in the midst of the universe, while the sun, moon, and stars revolved around it. The

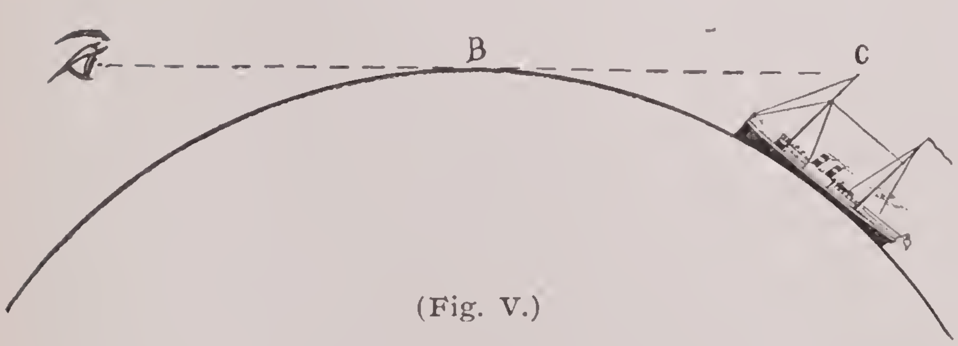
idea that the Earth was round gradually became accepted, and about three hundred years ago it began to be understood that there was a resemblance between the Earth and the heavenly bodies. We know that instead of being the center of the universe, the Earth is one of a number of bodies called *planets*.

These planets all revolve about the sun in paths, called *orbits*, which are nearly circular. A number of the planets have *moons*, or *satellites*. Wherever one of these exists it revolves around its planet and moves with it in its orbit around the sun. The sun, the planets, and their moons together form what is called the solar system.

There are eight large planets, and there are also several hundred small ones, called asteroids. The members of the solar system are our nearest neighbors in the heavens, and are near enough for us to be able to learn a good many things about them. Later, we shall take up some of the more important facts about the sun and the planets. For the present, let us give our attention to the planet on which we live.

The Earth is shaped like a ball and is slightly flattened at two opposite points called the *poles*. There are a number of ways of proving that the Earth is round, some of which may be known to you from your study of geography. The fact that men can sail around the world and return to their starting point is sometimes called a proof of this fact, but it is not really so. If the Earth were cheese-shaped, as was once thought, men could still sail around it. The shadow of the Earth that is thrown on the moon when it is eclipsed, is always circular. This could not be true if the Earth were not round.

If there are no hills, trees or buildings to interfere with our outlook, we always find the horizon circular. On the ocean, for instance, the sky and water seem to meet in a circle, of which the observer is the center. This circular horizon is another proof that the Earth is round. When we watch a ship sailing away from us over the ocean, the top of the mast is the part we see longest. (Fig. V.) Now the hull of the ship is its largest part, and if the earth were flat, it would be the part we should see last; but since the Earth is round, the lower part of the outward-bound ship is lost to sight first, while the highest parts are the last to disappear. This is one of the most convincing proofs that the Earth is round.

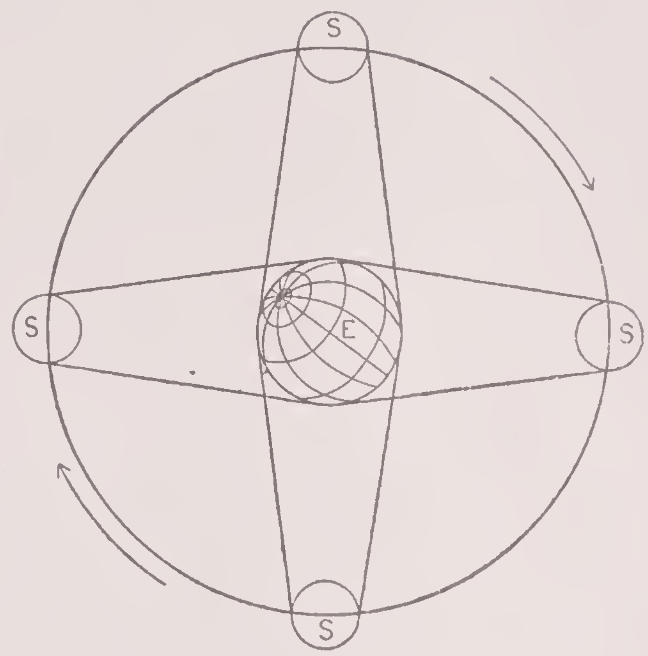


(Fig. V.)

The power which the sun has to hold the planets in their orbits is called *gravitation*. This is simply the attraction of matter for matter,

which was discovered by Sir Isaac Newton, about two hundred years ago. So far as we know, gravitation exerts the same power throughout all the universe, and every particle of matter attracts every other particle.

The sun is the largest mass of matter in the solar system, therefore it has the greatest power of attraction for us. The laws that govern the attraction of matter for matter are known, and by the application of these laws, and by careful observations of the different members of the solar system, astronomers have been able to find the weight and size of each one of these bodies. As stated before, the Earth's diameter is known to be about eight thousand miles. Its weight has been found to be greater in proportion to its size than would be the case if it were no denser, at great depths, than it is on the surface. We are sure, therefore, that the interior of the Earth is very dense — as dense, perhaps, as the heavier metals.



(Fig. VI.)

Day and night are the result of the Earth's rotation on its axis. As the Earth turns from east to west, one part of it after another is exposed to the sun's rays. In Fig. VI., it may be seen that the apparent daily motion of the sun around the Earth, which is really the Earth's rotation on its axis, causes different portions of the Earth to receive the sun's rays at different times, and thus, while it is night in one place, it is day in another. Let us think of the different cities, London, Chicago, and San Francisco.

As the Earth rotates so as to bring London into the sunshine, the people there will first see the dawn; then the sky will grow lighter and lighter, until they are brought where they can actually see the sun and, as we say, the sun rises in London. The Earth continues to rotate, and London is brought more and more directly under the sun, until, at noon, that body occupies the highest point it will reach in the London sky that day. Then, as the Earth still rotates, London will be gradually moving out from under the sun. The appearance is that of the sun moving from the highest point in the sky, lower and lower, until it reaches the horizon, and the sun sets; that is to say, London is carried out of sight of its rays. For some little time after sunset a faint light, called twilight, remains in the sky, but the Earth continues to rotate, and gradually London is carried entirely out of the sunlight.

Chicago is about six hours behind London, as to the time of sunrise, noon, sunset, etc. When it is noon in London, it is about the

time of sunrise in Chicago. As we go farther west and reach San Francisco, we find that it is almost two hours behind Chicago, and that when it is noon in San Francisco, it is two o'clock in the afternoon in Chicago. If we try to set our clocks and watches exactly by the place of the sun in the sky, we shall have to keep changing our time as we travel east or west. For instance, there is a difference of twelve minutes between the time of noon in New York and in Washington. To be constantly changing the reading of our timepieces in this way would be very inconvenient, and it is not now necessary.

The United States has been divided, from east to west, into four sections, in each of which the time of a point near its center is used. Thus, four different kinds of time are used throughout this country. These four kinds of time are known as Eastern Time, Central Time, Mountain Time and Pacific Time. Eastern Time is about the correct time for Utica and Philadelphia; Central Time is nearly correct at St. Louis; Mountain Time is nearly right at Denver, and Pacific Time is ten minutes faster than the correct or local time at San Francisco.

The sun crosses our meridian every day, and when it is on the meridian, we say it is noon. From noon one day until noon the next, is an interval that we divide into twenty-four hours. We call this interval of time a sun day, or solar day. As the length of time from noon to noon varies a little during the year, it has been found convenient to adopt a standard day, which is the average in length of all the three hundred and sixty-five days of the year. This standard day is called the *mean solar day*. All clocks and watches that we use in daily life are regulated to keep mean solar time.

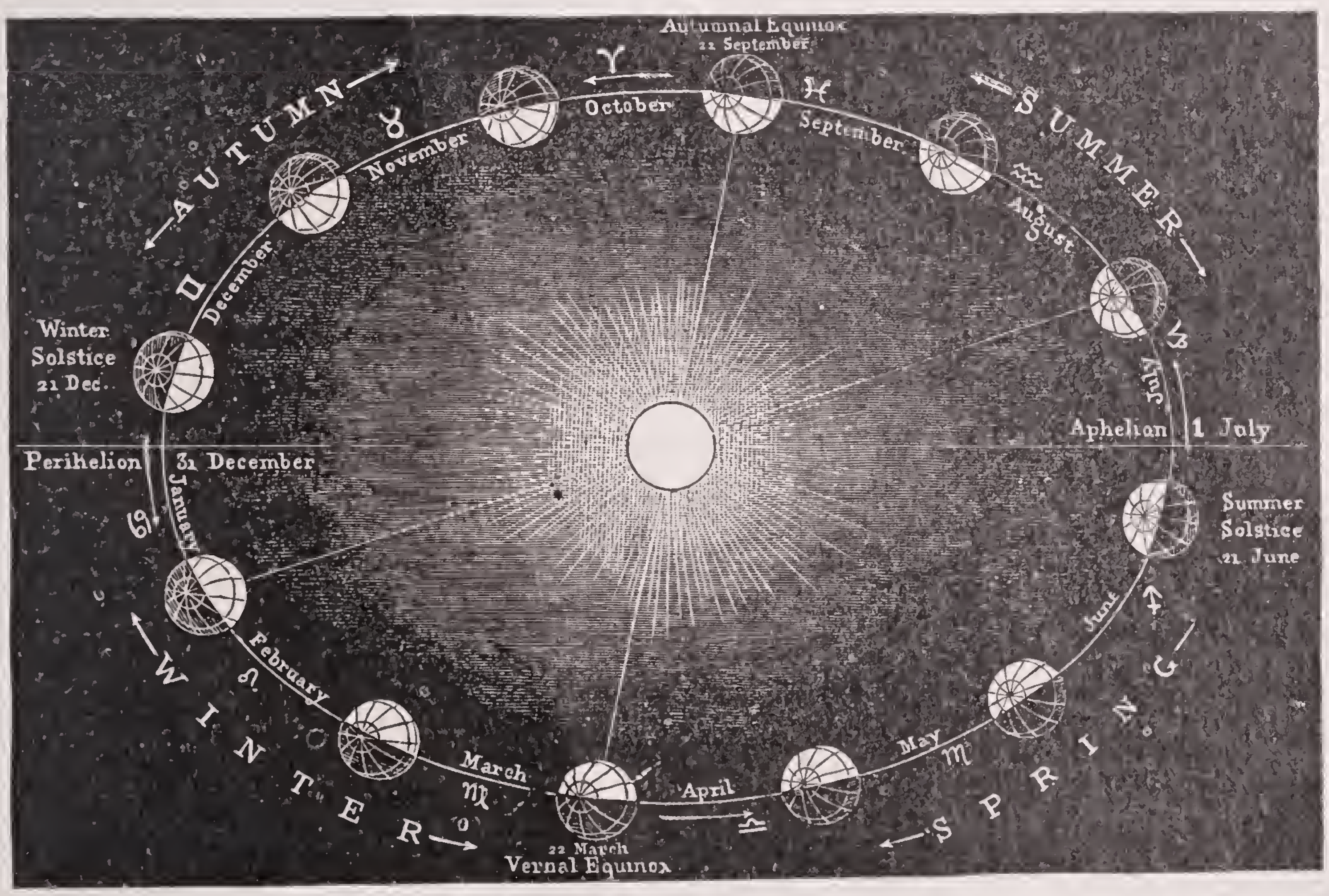
There is another kind of time in use in observatories called star time, or *sidereal time*. The length of a sidereal, or star day, is found by observing the interval between the times at which a certain star crosses our meridian, on two successive days. The star day differs in length from the sun day, because the sun does not remain in a fixed position among the stars, but is constantly moving eastward. It moves far enough every day to make the difference between the sun day and the star day amount to about four minutes.

Star days are all of exactly the same length. Each one is as long as the time which it takes the Earth to rotate on its axis. The star day, like the sun day, is divided into twenty-four hours, each star hour being a little shorter than a sun hour. There are three hundred and sixty-six star days in the year. Every large observatory has a sidereal clock, as well as a mean solar clock. The two clocks read exactly the same at only one time during the year, about the twenty-first of March, which is called the *Vernal Equinox*.

We have been using the word day as meaning an interval of twenty-four hours. When we speak of day and night, however, we mean by day the length of time that the sun is above the horizon and it is light. The length of this kind of day, as you know, varies greatly during the year. Twice a year, about March 21 and September 21, the days and nights are of equal length. These times are called the *spring equinox* and the *fall equinox*. After the spring equinox, the days gradually grow longer, until about June 21, which is generally the longest day in the year. After this date the length of the days slowly decreases until, at the time of the fall equinox, day and night are again equal.

The days continue to grow shorter after the fall equinox, until about December 21, when we have the shortest day of the year and the longest night. After this date, the days again gradually grow longer, and day and night are again equal about March 21.

Fig. VII. illustrates the way in which the seasons are caused by the motion of the Earth in its orbit.



(Fig. VII.)

The length of day and night is the same all over the world at the times of the equinoxes. At other times there are great differences in the length of the day at different places, the differences at any time depending upon the distances from the equator of the points of reckoning. At the equator, all days and nights are equal; but the

farther we go either north or south of the equator, the shorter become the short days of the year and the longer become the long days. June days are appreciably longer in Minnesota than in Louisiana.

At the poles, the year consists of but one day and one night, each six months in length. No one has as yet reached either pole, but arctic explorers have gone so far north as to find the nights several months in length. There are a number of places in the far north of Europe where the sun does not set for a number of days in midsummer. These places are often visited by tourists, for the sake of enjoying the strange sight of the sun shining at midnight,—the so-called "midnight sun."

Besides rotating on its axis, the Earth, as you have been told, moves in its orbit. We can see the effect of this motion in the change of the sun's position among the stars. This change was noted by early astronomers. They, of course, could not see the stars that were close to the sun at any time, for the sunlight quite hides the stars near it. But they would naturally observe what bright stars appeared in the west soon after sunset, what stars were near the meridian at midnight, and what stars were in the east before sunrise.

By noticing the positions of the stars, at different seasons of the year, they were able to calculate with a fair amount of accuracy the sun's yearly path among the stars. This path they called the *ecliptic*, because eclipses of the sun or moon always took place within it. The ecliptic passes through various groups of stars and near many bright ones, and the early astronomers noticed that the planets and the moon are always found within a short distance of the ecliptic.

From what you know about angular measurement, you will understand what is meant when you are told that the planets are never found farther than 8° from the ecliptic. The sun's apparent motion in the ecliptic is due to the real motion of the earth in its orbit. The apparent paths of all the planets lie within a part of the celestial sphere that is only 16° in width. This forms a sort of narrow belt, or zone, upon the surface of the celestial sphere, and in it the planets move along paths inclined to each other at small angles.

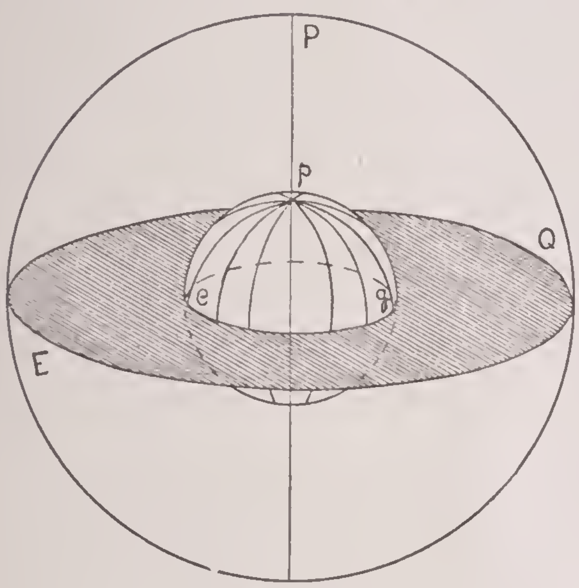
The planets all lie in nearly the same plane, hence the solar system may be described as circular and flat. A special name was long ago given to that part of the heavens that lies between 8° north and 8° south of the ecliptic. It is called the Zodiac. There are twelve important star groups, or constellations, lying either entirely or chiefly in this belt.

The Zodiac is sometimes said to be divided into twelve signs, each sign being named for one of these constellations. It might be well to learn these signs of the Zodiac, for it is often convenient to

know them. Here is a rhyme by Watts, the English hymn writer, which gives them in convenient form:—

"The Ram, the Bull, the Heavenly Twins,
And next the Crab, the Lion shines,
The Virgin and the Scales;
The Scorpion, Archer and He-goat,
The Man that bears the watering pot,
And Fish with glittering tails."

The Earth's equator, as you know, is an imaginary line which passes around the Earth midway between the poles, and is everywhere 90° distant from each of them. If we suppose the plane of the Earth's equator to be extended until it cuts the celestial sphere, the circle thus described will be what is called the *celestial* equator. (Fig. VIII.)

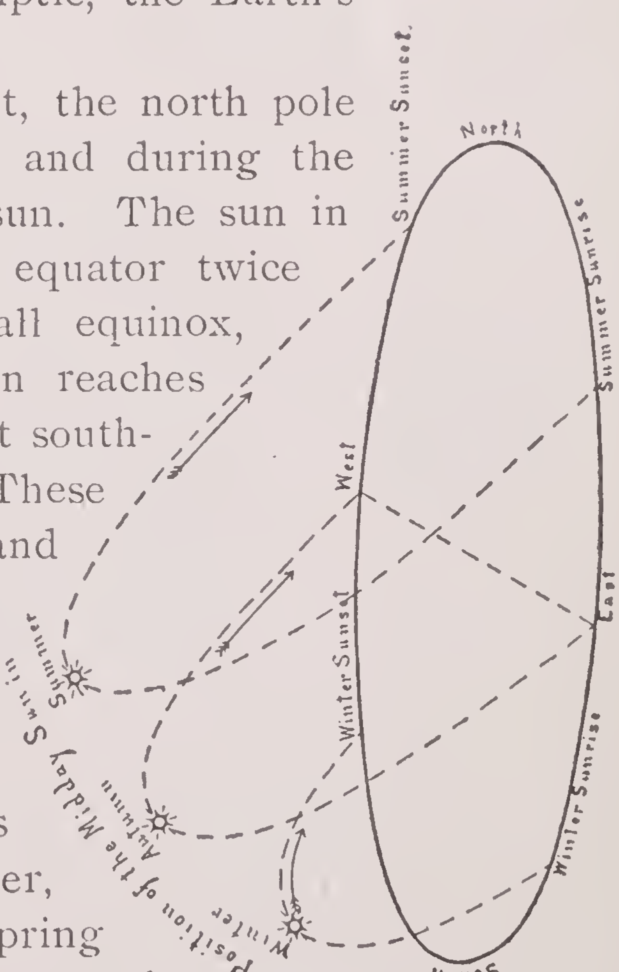


(Fig. VIII.)

The ecliptic is another great circle on the celestial sphere, and is formed by the intersection of the plane of the Earth's orbit with the celestial sphere. The angle between these two great circles, the celestial equator and the ecliptic, is twenty-three and one-half degrees. As a result of this angle between the equator and the ecliptic, the Earth's axis is tilted toward the sun.

As the Earth moves around the sun in its orbit, the north pole tips toward that body during one-half of the year, and during the other half it is the south pole that tips toward the sun. The sun in its apparent motion around the ecliptic crosses the equator twice each year. These are the times of the spring and fall equinox, of which we have already spoken. In June the sun reaches its most northern position, and in December its most southern position, as seen from the Earth. (Fig. IX.) These two periods are spoken of as the *summer solstice* and the *winter solstice.*

The accompanying figure shows the sun's apparent daily paths above the horizon at the times of the equinoxes and the solstices. By looking carefully at this figure, we can see from it two reasons why we receive the most heat from the sun in summer, least heat in winter, and a moderate amount in spring and fall. One reason for the difference in the amount of heat that we receive at different seasons is the variation in the length of time that the sun is above the horizon. The other

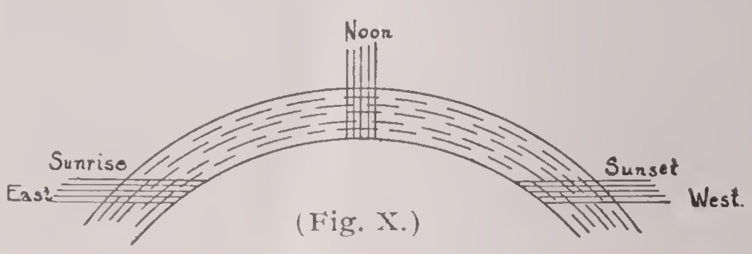


(Fig. IX.)

reason is, that the direction of the sun's rays also varies with the seasons.

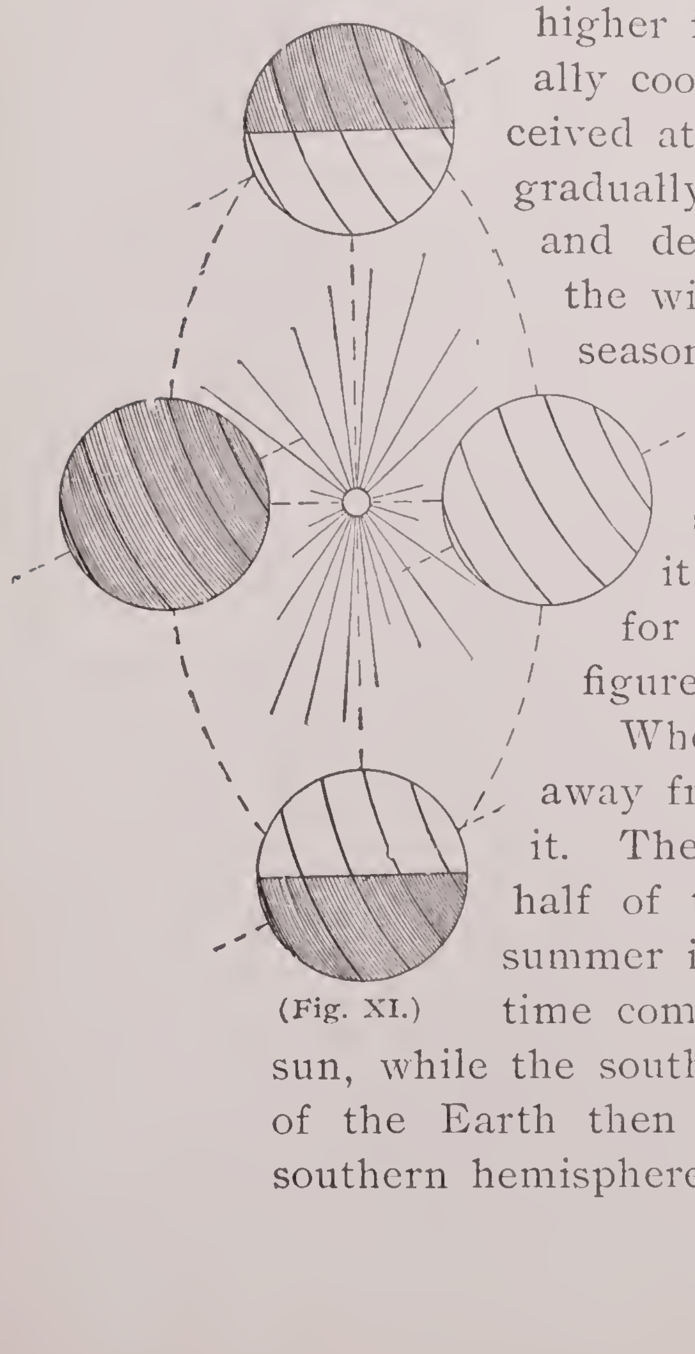
You have doubtless noticed that in midsummer the sun is above the horizon much more than half of the twenty-four hours, while in midwinter the opposite is true. The summer nights are so short, that the air and land do not have time to lose much of the day's heat, before the sun is again in the sky. In the winter, the nights are much longer than the days. The Earth has hardly time to warm itself in the sun's rays, before the sun sets, and the heat that has been received begins to disappear.

In summer, the sun at midday is almost directly overhead. Now the more vertically the sun's rays strike a surface, the warmer that surface becomes, simply because more rays fall upon it. We see evidence of this daily. At night and morning, when the sun is near the horizon, we receive much less heat than we do at midday, when the sun is more nearly over our heads. The reason for this is apparent from the accompanying figure. (Fig. X.)



(Fig. X.)

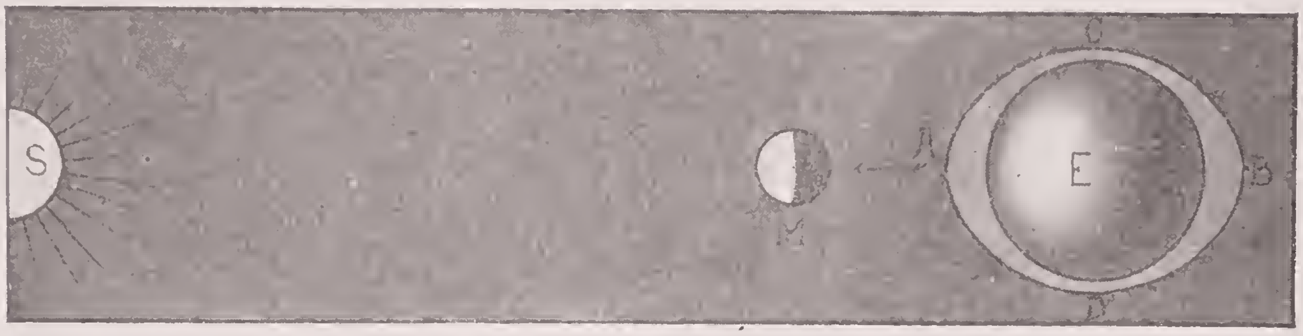
In general, the day becomes warmer as the sun rises higher and higher in the sky, is warmest at about noon, and gradually cools off toward nightfall. Similarly, the heat received at noon, at any place in the United States, increases gradually from the winter solstice to the summer solstice, and decreases gradually from the summer solstice to the winter solstice. In the southern hemisphere, the seasons occur in the same order as in the northern hemisphere; but there is six months difference in the time of the seasons in the two hemispheres, so that when it is winter in the former, it is summer in the latter, and so on. The reason for this difference is shown in the accompanying figure. (Fig. XI.)


(Fig. XI.)

When it is winter with us, the north pole is tilted away from the sun and the south pole is directed toward it. The sun's rays fall more vertically on the southern half of the Earth than on the northern half, and it is summer in the southern hemisphere. When our summer time comes, it is the north pole that is tilted toward the sun, while the south pole is tilted away from it. The northern half of the Earth then receives the more nearly vertical rays, while the southern hemisphere receives the more oblique ones.

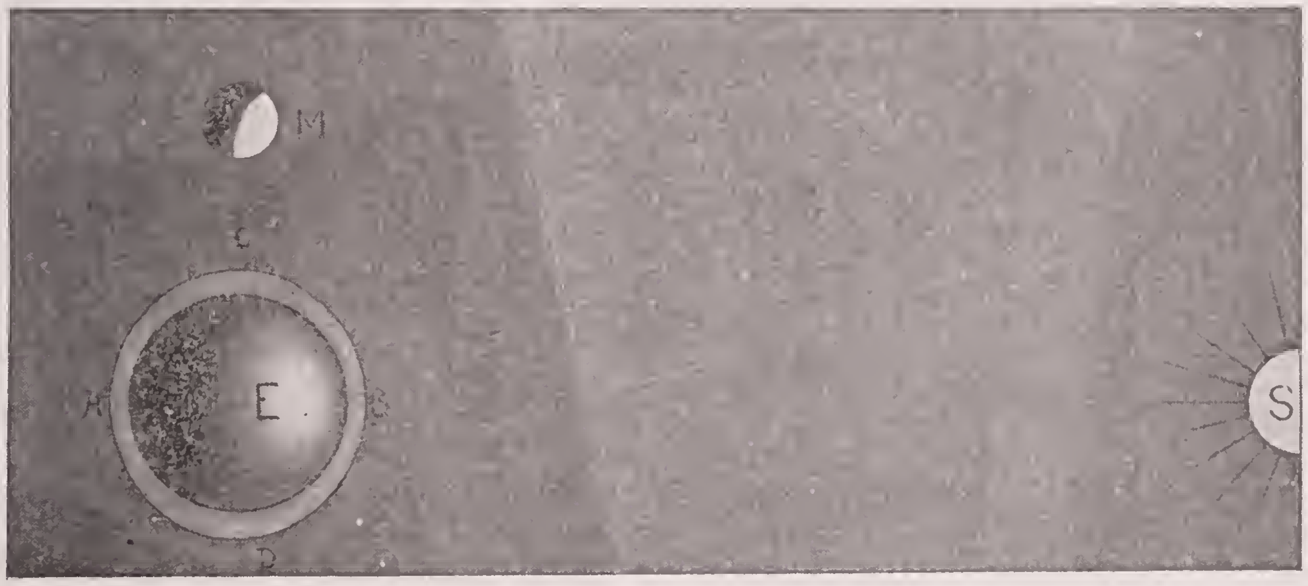
That remarkable property of matter known as gravitation, which has already been mentioned as the force that keeps the planets in their orbits, manifests itself in another way. Its largest and most important effect is its action in retaining the planets in their orbits around the sun, and the moons in their orbits around their planets; thus controlling all the motions of the solar system.

Another and smaller effect of gravitation is seen in the tides, which continually rise and fall on the shores of the oceans, and other large bodies of water. The tides are caused by the attractions of the sun and moon. At new moon and full moon the sun and moon act together, and produce very high tides, which are called *Spring Tides.* (Fig. XII.)



(Fig. XII.)

At the moon's first and third quarter, the sun and the moon act in opposition to each other, and the lowest, or neap, tides are produced. (Fig. XIII.) The sun, although much larger than the moon, is so far away, that its tide-producing power is less than one-half that of the moon. For the sake of simplicity, let us consider the tides produced by the moon, as they would be, if not modified by those produced by the sun. Let us remember that while the Earth attracts



(Fig. XIII.)

the moon with sufficient force to retain it in its orbit, the moon also attracts the Earth. The power of this attraction at any part of the Earth depends upon the distance of that part from the moon. The attraction is strongest on the side of the Earth nearest the moon, and least on the opposite side. If the Earth were soft, it would be pulled out of shape; but since it is rigid, its shape is not distorted, and it is only the water on the surface of the Earth that is noticeably affected

by the attraction of the moon. Since water is fluid and responds readily to any force that acts upon it, the water on the side of the Earth toward the moon, is drawn toward that body. The Earth, being nearer the moon than the water on the opposite side, is drawn away from the water.

In this way two tides are produced at the same time, one on the side of the Earth toward the moon, and one on the opposite side. The rotation of the Earth on its axis, from west to east, causes the tide to move westwardly over the ocean. Out in the open ocean the rising and falling of the water twice a day is not seen by people on board a ship, because the ship itself rises and falls with the water; but on the shores of the sea the rise and fall of the water is something familiar to all who have lived near the ocean. The height to which the tide rises varies in different places, being higher on the eastern coast of the continents than on the western. The tide rises higher in bays and estuaries, than it does on capes and headlands.

In the Bay of Fundy the tide sometimes rises to a height of seventy feet or more. The tides also run up rivers to great distances, and this, too, often in spite of a strong current. This matter of the tides is an interesting subject, which can only be treated very briefly here, but there are many curious things about the tides which you may learn later on.

They have produced a great impression upon the human mind, and are often referred to in literature, and used as a means of illustration. For example, ships often come into port at high tide when otherwise the water would be too shallow. Shakespeare may have had this fact in mind when he wrote these words, which should be remembered by everyone:—

"There is a tide in the affairs of men, which, taken at its flood, leads on to fortune."

THE SUN

There is nothing in the sky that compares with the Sun in magnificence. In fact, it is the most striking object in nature. Its splendor is too great to permit of its being watched with the naked eye, unless it is hidden by clouds or haze. But even if we cannot look directly at it, we are always conscious of its presence or absence. Stars may rise and set without our being interested in the fact, but when the Sun rises, it becomes light, we can see each other's faces, and can safely go about and undertake many tasks that are impossible in the darkness.

When the Sun sets it becomes dark and all activities must cease, except such as can be carried on by artificial light. In the summer we try to shield ourselves from the Sun's rays, for the heat, which is so necessary to ripen corn and other grains, is greater than we can easily bear. In winter, we try to spend what time we can in the direct sunshine, and we find its warmth most grateful.

It is hard to realize that the fixed stars are all suns, many, perhaps most of them, larger than our own Sun, but so far distant from us that we see them only as points of light. Just as the Sun, when seen from the earth, outranks all other heavenly bodies in beauty and brightness, so its importance to us also outranks that of all the others. As has been said before, the Sun is the center of the solar system, and is by far its most important member, since it is the attraction of the Sun that retains the planets in their orbits.

Almost all the light and heat that we receive come from the Sun. The light of the stars is very faint, and moonlight is merely reflected sunlight. We know of no form of life that does not depend on the Sun, in some way, for its very existence. Plant life thrives with sunshine and rain. It receives both of these from the Sun, for rain falls from the clouds, and it is the heat of the Sun that has caused the moisture to rise from the sea and form clouds. Animal life depends for its food on plant life, so we can easily see that it is the Sun that keeps everything alive.

In ancient times men worshiped the Sun. They were impressed with its splendor and partly understood how much they owed to it. We now know that there are many benefits that we receive indirectly from the Sun which are as important as the more apparent ones. The winds that blow, and the snow that covers the grass like a blanket and protects it in winter from the most severe cold, are due to the Sun, just as truly as are the light and warmth that we receive directly from the Sun's rays.

The wood that we use for building material, for furniture and for fuel, grew with the Sun's aid. Coal, as you know, is useful to us in very many ways, in warming our houses, in furnishing the power for railway trains, steamships and many forms of manufacture,— in fact, it would be hard to imagine the world of to-day without coal. It, too, we owe to the Sun, since it was formed from forests that grew ages ago by the aid of the Sun's rays.

Let us see what are some of the most important facts that have been discovered about the Sun. The surface that sends out the light that we receive is called the *photosphere*. In looking at the photosphere with the telescope, we should, perhaps, expect to see a smooth, shining, golden surface. That which is really seen appears like brilliant

grains scattered over a background that is less brilliant. This appearance is sometimes described as like snowflakes, scattered over a gray cloth, and the brilliant grains are often referred to as *rice grains.*

Although they appear very small when seen in the telescope, we know that they are really of considerable size. Two of them, laid side by side, would extend from New York to Chicago. Here and there over the Sun's surface appear streaks, called *faculæ*, which are even more brilliant than the rice grains. These are probably masses of the same material as the rest of the photosphere, extending higher than the general level. The rice grains and the faculæ are probably luminous or shining clouds, floating in an atmosphere that is less luminous.

Dark spots often appear on the Sun's surface. These differ greatly in size, and the largest spots can sometimes be seen without a telescope. When seen thus, they look like very small, dark specks.

As seen with a telescope, they are very interesting, since they change in appearance from day to day. When fully formed, and before they begin to break up, they are usually circular in shape. They have very dark centers, and around the center is a sort of fringe that is less dark. By watching these spots in their different positions on the Sun's surface, it has been found that many of them, at least, are hollows in the photosphere. When a spot is at the edge of the Sun, we can sometimes see plainly that it is cup-shaped. The hollows are probably filled with gases that are less hot than the photosphere itself, and consequently they appear dark in comparison with its brilliancy. Sometimes weeks will pass without a sun spot being visible, while at other times they can be counted by hundreds.

It cannot be foretold just when and where a new spot will be found on the Sun's disk, but it is known that there is a certain regularity in the times of their coming. Every eleven years the spots are very numerous. Sun spots usually last several weeks, or even months. By watching the spots from day to day, it has been found that the Sun, like the earth, revolves on its axis. Wherever a spot may appear on the Sun's disk, each succeeding day finds it somewhat nearer the Sun's western edge, or limb. When it reaches the limb, it disappears from view.

After about two weeks, the same spot may be seen reappearing upon the Sun's eastern limb. By observing the rate at which the spots move, it has been found that the Sun rotates on its axis once in about twenty-five days. Strange to say, the Sun does not seem to revolve as a whole, but the part near its equator appears to revolve more rapidly than the rest.

Outside the photosphere, the Sun is surrounded by an envelope of gases, called the *chromosphere.* This is never seen with the naked

eye. Neither can it be seen with a telescope, except during the time of a total eclipse of the Sun, for at other times it is hidden by the bright light of the photosphere. It is of a brilliant scarlet color, and is described by those who have been fortunate enough to see it as a "sea of flame."

Out of this chromosphere rise irregular jets of flame called *prominences*. These are extensions of the chromosphere, or clouds of the same gases. With an instrument, called the *spectroscope*, you can see the prominences in full daylight, without waiting for a solar eclipse.

The Sun has another gaseous envelope of great beauty, called the *corona*, a Latin word that means "crown." The corona can only be seen when the Sun is entirely eclipsed, but it can then be seen with the naked eye. It shines with a pearly light, and surrounds the darkened disk of the Sun in such a way as to suggest the halo that early artists placed around the heads of the saints. When seen in the telescope, the contrast between the corona and the scarlet prominences is very striking. It is not yet very clearly known what the corona is, or what purpose it serves.

We have learned that the Sun is surrounded by envelopes of gases and luminous clouds, but nothing has, as yet, been said of the constitution of the Sun itself. Although no one has ever been able to look through the photosphere and see what is beneath it, there is every reason to think that the ball, or *nucleus*, within is also made up of gases at a very high temperature. We know enough of the nature of the photosphere to be sure that no cool or solid matter could exist within it.

By examining the Sun with the spectroscope, we have learned that many substances known to us on the earth exist on the Sun as gases. Among these are the metals, iron, silver, copper, and platinum. Those of you who have ever visited a foundry know something of the great heat necessary to melt iron into a liquid, and can faintly imagine how intense the heat must be at the Sun's surface, where iron exists as a vapor.

The earth receives only a very small part of the Sun's heat, and it is well for us that this is so. Astronomers estimate that if all the Sun's heat were collected on a mass of ice as large as the earth it would melt the ice in two minutes, boil the water thus produced in two minutes more, and turn it all into steam in less than a quarter of an hour from the time the heat was first applied. The only light with which we are familiar that at all approaches the brilliancy of sunlight is the electric arc light. The central part of an arc light is something like one-third as bright as the Sun's surface.

The Sun is about ninety-three million miles from the earth. This is an important number to remember, as it is called the *unit of celestial*

measurement. All other distances of planets, stars, and other heavenly bodies are first found in terms of this unit. The Sun and moon as we see them in the sky appear to be of about the same size. This is because the moon is so very much nearer to us than the Sun is. In reality the moon is much smaller than the earth, while the relative sizes of the Sun and the earth are something like those of a bushel basket and a pea.

The fires that we are familiar with on the earth are apt to burn themselves out in time. At all events, fresh fuel frequently has to be added. It would be a serious matter for us if the Sun's fires were to die out and its surface grow cold. We receive now just about enough heat from the Sun for the world as a whole to exist in comfort. We could still exist were this heat a little less. But if it should become very much less, the higher forms of life would disappear from the earth.

You see we are much interested in the question of the Sun's heat, and would like to know whether it is likely to remain the same indefinitely and what the causes are that maintain it. Although it is possible that the amount of heat we receive from the Sun may vary a little from day to day and from hour to hour, we are quite certain that there has been no great change in the amount since the earliest times of which we have any record. Judging the future by the past, then, we need not fear any change in conditions as they now exist for a very long time.

Astronomers have given much study to the question of the origin of the Sun's heat. For want of a better explanation, it was for a long time supposed that the Sun was really burning. But now, strange as it may seem, it is accepted as a scientific fact that the Sun's heat is maintained by shrinkage due to its own cooling. As has been said, the heat of the Sun is so intense that no known substance can exist there, except as a gas.

It is also true that the Sun's weight is so small in proportion to its bulk, that we have another reason for thinking it must be gaseous. The great gaseous globe of the Sun is constantly giving out heat or cooling. In the process of cooling, the Sun shrinks, and this shrinkage produces heat in such great quantities that the sun remains as hot as ever, but becomes somewhat smaller. But how can this shrinkage produce heat? In the same way that a blacksmith's hammer is made hot by striking it on a cold anvil.

Heat is only a form of energy and may produce mechanical force, or be produced by it. We see this every day in the locomotive steam engines on the railways. The heat of the burning coal produces the mechanical energy which causes the engine to move, and

the mechanical energy thus produced may again become heat. An example of this is the "hot box," where great heat is produced by friction when an axle of an engine or car is not properly oiled. When the gaseous Sun gives out heat and shrinks, each particle moves toward the center, and in so doing strikes other particles, is stopped by them, and heat is thus produced.

The amount of mechanical energy needed to produce a given amount of heat is known, and it has been calculated that if the Sun shrinks enough so that its diameter becomes every year three hundred feet shorter, the amount of heat thus produced will be enough to make up for the heat that the Sun gives out during the year. This amount of shrinkage is too small to be detected by any measurements we can take at our great distance from the Sun, but there is every reason to think that this is the true explanation of the Sun's heat.

Of course if the Sun is thus shrinking, a time will come when it will no longer be mainly gaseous, and will send out less and less heat. When this time comes the earth's summers will grow cooler, and its winters will become more intensely cold, until at last it will be too cold for life to exist here any longer. This prospect, however, is nothing that need make us unhappy, for we have no reason to fear important changes in the Sun's heat for millions of years.

THE MOON

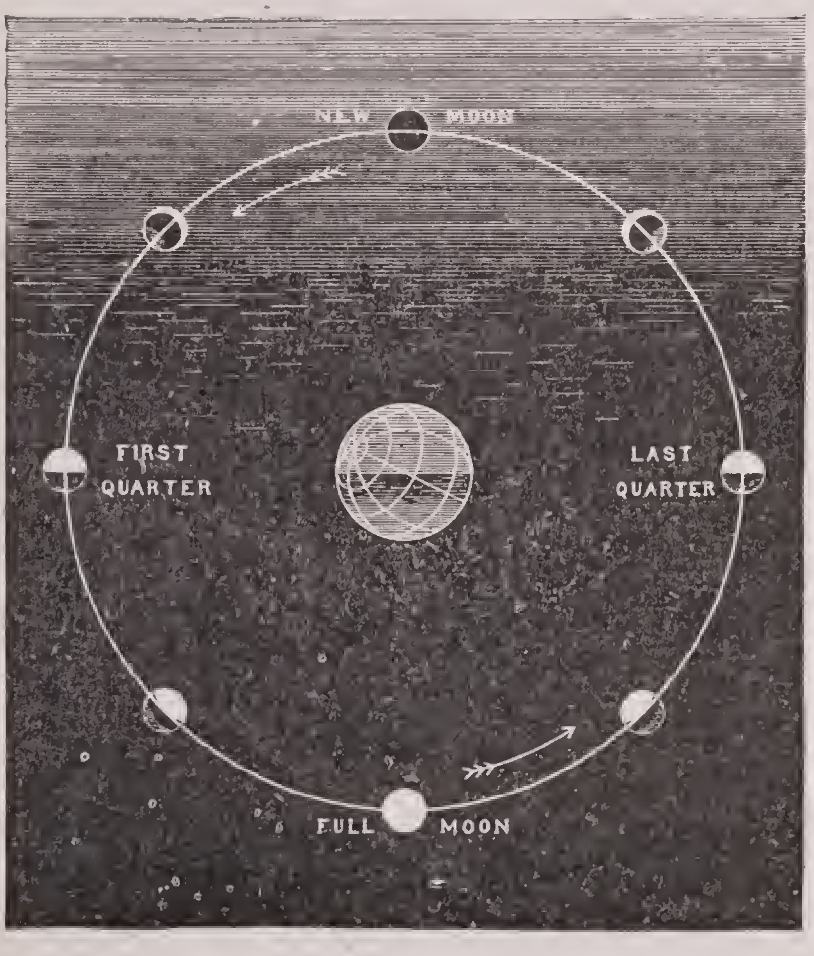
After the sun, the Moon next claims our attention. It is the only object regularly seen in the heavens, which can at all compare with the sun in apparent size and in interest. It appears as large as the sun, although, as has been mentioned, it is in reality much smaller than the earth. It is, in fact, our nearest neighbor in the heavens, and stands in somewhat the same relation to the earth, that the earth does to the sun.

True, the earth does not furnish the Moon with heat, and sends it only a small amount of light, but the earth's attraction causes the Moon to revolve about it as the earth revolves about the sun. Since it revolves about the earth, the Moon is, of course, carried with the earth in its yearly journey around the sun. The amount of reflected sunlight that comes from the Full Moon is very small, when compared with the light of the sun itself. Astronomers tell us that six hundred thousand Full Moons would be required to equal the sun in brightness. The Moon is often visible in the daytime, and we can

then compare its brightness to that of floating clouds. Both Moon and clouds reflect the sun's rays and neither of them has light of its own.

Besides the light it furnishes us, the Moon gives us aid of an entirely different kind, in causing the tides. If there were no Moon, the tides, which, as has been said, are chiefly due to the Moon, would then be due to the sun alone, and would be smaller than they are. Evidently, we should feel the loss of the Moon more than that of any other heavenly body, except the sun.

While the sun always appears as a huge round disk, the Moon changes its appearance from night to night. Sometimes it appears in the western sky as a silvery bow, or crescent, which we call the New Moon. From night to night the bow increases in width, until the Moon appears semicircular in shape, and is said to be in its *first quarter*. After the first quarter, the Moon continues to increase in size, until we finally see a round disk, which we call the *Full Moon*.



(Fig. XIV.)

These different shapes which the Moon assumes are called its *phases*. (Fig. XIV.) The Moon is said to be *gibbous* when the phase it presents is more than the quarter and less than the Full Moon. After Full Moon comes a gradual decrease in size. All the phases that appear between New Moon and Full Moon are repeated, but in exactly the opposite order. First the Moon is gibbous until the third quarter; then it becomes *crescent* and grows narrower and narrower, until at last it is again only a silvery bow. After the last phase, the Moon is invisible for a few days, when it again appears as the New Moon, in the western sky, soon after sunset.

The crescent New Moon, however, faces in a different direction from the crescent Old Moon. When the Moon is new, the outer edge of the crescent, which is part of the outline of the Moon's disk, is turned toward the west. Through all its phases until the time of Full Moon, this edge or limb of the Moon continues to point westward. After Full Moon, it is the eastern limb of the Moon that remains in view, while the changes take place from the western limb, so that when the crescent Old Moon appears, its outer edge is turned eastward.

The reason of the different phases of the Moon is not hard to understand. That half of the Moon that is turned toward the sun is brilliantiy lighted up, while the half that is turned away from the sun is dark. As the Moon moves around the earth, it assumes, each day, a different position, relative to the earth. Whether we see all or part of the brilliant half of the Moon, depends upon the positions of the earth and the Moon with reference to each other. If we see the whole of the brilliant half, we say the Moon is full. If we see but a quarter, the Moon is in either its first or its third quarter, and so on.

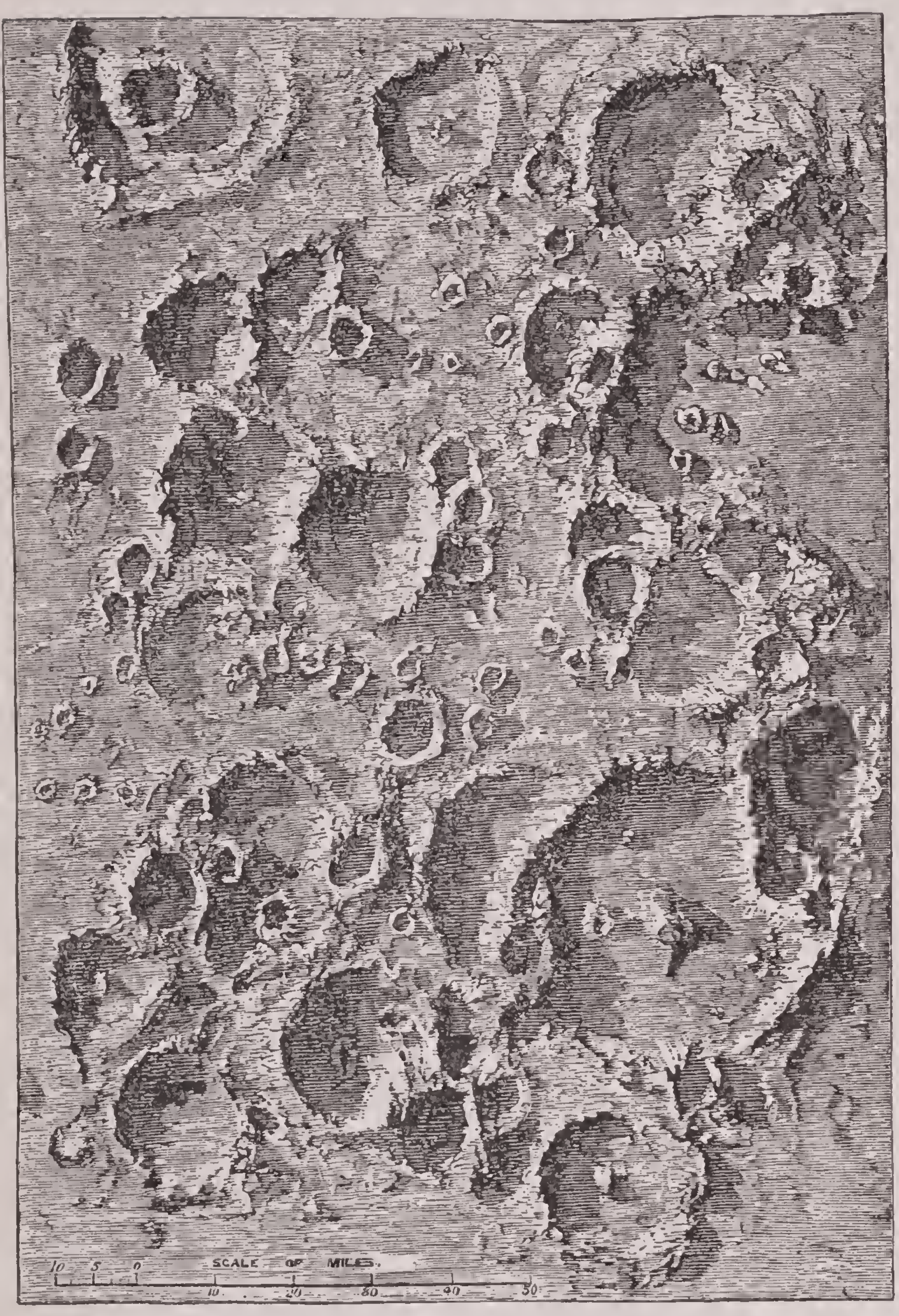
Often when the Moon is new, we can see, besides the silver crescent, the dark part of the Moon very faintly illuminated. This curious appearance is often called "the old Moon in the young Moon's arms." The part of the Moon that is so dimly lighted up is not illuminated by direct sunshine, but by light reflected from the earth. The sun shines on the earth, the earth reflects some of this light to the Moon, and the Moon reflects it back again to the earth. No wonder the light is dim, after all this passing back and forth.

The interval from one New Moon to the next, is a natural division of time that was observed very early in the history of mankind, and we find that it is observed even by savage peoples. We see traces of the word Moon in our word *month*. And although the twelve months into which we divide our year, do not strictly agree with the length of time from New Moon to New Moon, we often use the words *lunar month*, meaning four weeks.

The real length of a lunar month is twenty-seven and one-third days, instead of twenty-eight days. Like the sun, the Moon seems to move north and south among the stars, as well as from east to west. By measuring the angular distance between the Moon's position when farthest north and farthest south, we can find the angle its orbit makes with the equator and also the angle it makes with the ecliptic. The angle between the Moon's orbit and the ecliptic is about five degrees. This means that when the Moon is in its most northern position among the stars, it is five degrees farther north than the sun ever is, and that its most southern position is five degrees south of any point on the celestial sphere ever reached by the sun.

To find our distance from any of the heavenly bodies, may seem at first a hopeless task. In reality, it is one of the simpler problems of astronomy. The distances of all the principal members of the solar system are known. There are even a number of the fixed stars whose distances have been learned. The methods used are so simple, that they can easily be understood by anyone who has studied trigonometry.

The distance from the earth to the Moon is about two hundred and forty thousand miles. We have already learned that the earth's diameter is eight thousand miles. So we see that it would take thirty globes of our earth, piled one on top of another, to reach from the earth's surface to the Moon. The Moon's diameter is a little greater than one-fourth that of the earth. If the earth were divided into fifty equal parts, each part would be about the size of the Moon.



(Fig. XV.)

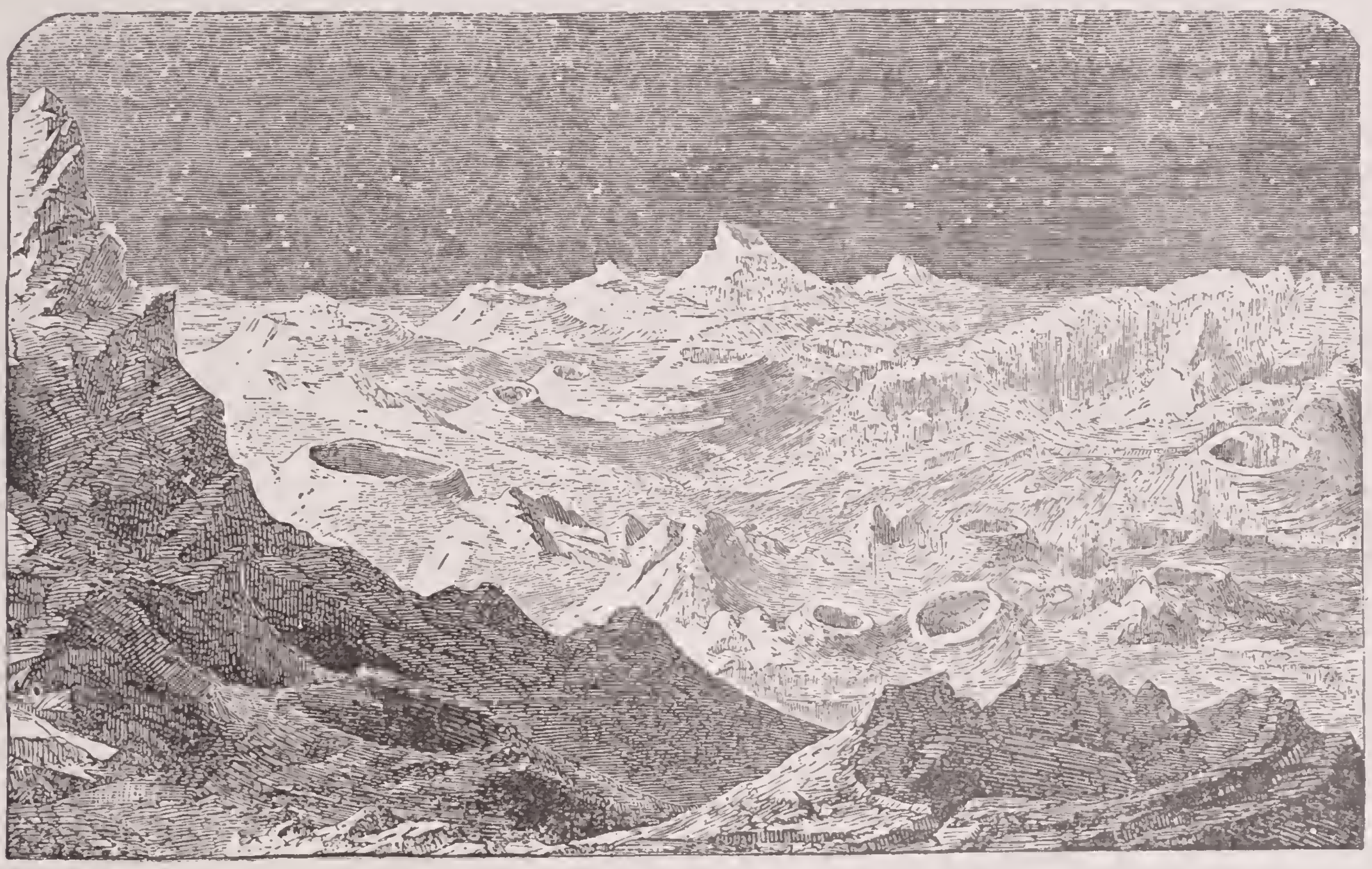
Astronomers are sure that there are no living creatures on the Moon, for it has neither air nor water, and we know of no form of life that can exist without these. The surface of the side of the Moon that we can see has been carefully examined with telescopes, and accurate maps have been made of it. (Fig XV.) Any object on the Moon with a diameter as large as half a mile can easily be seen in a telescope of moderate size.

Not much variety appears on the Moon's surface. There are no forests, lakes, rivers or oceans. There are, however, many scattered mountains and craters and some mountain ranges. The craters resemble the volcanic craters on the earth's surface, but are very much larger. The largest of the Moon's craters are more than a hundred miles across, while the largest craters on the earth are only six or seven miles in width.

Most of the Moon's craters are circular in shape and are surrounded by mountain ranges. At the center of the crater there often rises a group of mountains as high as the surrounding range. The origin of these so-called craters is unknown. No change appears in them from day to day, or from year to year. There is reason to think that they were once volcanoes, but if so, they have long been dead. If there has ever been life of any kind on the Moon, either vegetable or animal, it has left no trace.

The surface of the Moon is very cold. Since the Moon rotates on its axis once in four weeks, its days and nights are each two weeks in length. Each part of the Moon, in turn, goes fourteen days without a ray of sunshine to warm it. Then, for fourteen days the sun shines upon that side without interruption, but as there is no air to retain the heat, it is lost almost as soon as it is received. Astronomers think that even in the middle of the Moon's long day, its surface becomes only as warm as melting ice. In the middle of its nights, the cold is more intense than we can imagine. (Fig. XVI.)

The material of which the Moon is made is much lighter than that which composes the earth, and thus its power of attraction is less than that of the earth, even in proportion to its size. If it ever



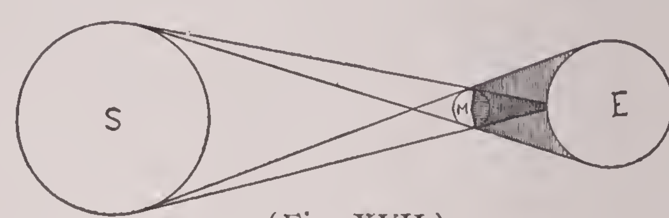
(Fig. XVI.)

had an atmosphere, like that which surrounds the earth, it may have gradually lost it through the lack of attractive power to hold it.

Among the most interesting things that occur in the sky are the eclipses of the sun and Moon. Doubtless most of you have seen a partial eclipse of one of these bodies. Some may even have seen a total eclipse. Whenever the sun is shining, we can notice the shadows cast by different objects that are in its light. Like smaller objects, the earth and Moon cast shadows that point directly away from the sun, which causes them. At the time of New Moon, the Moon is between the earth and the sun. If it is exactly between them, so that the three bodies are in a straight line, and if the Moon's shadow

is long enough to reach the earth, the sun will be hidden from that part of the earth where the shadow falls. (Fig. XVII.)

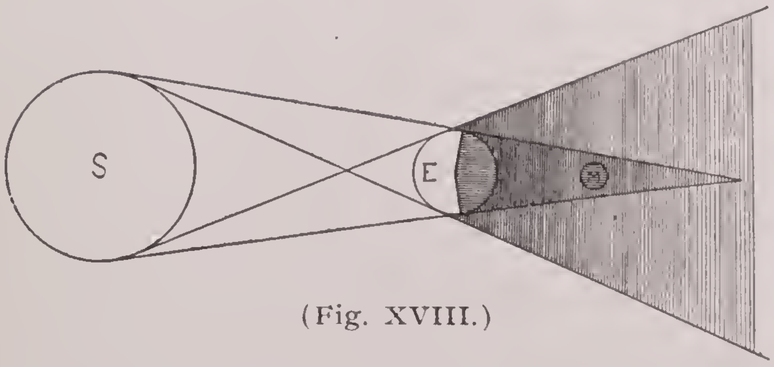
This hiding of the sun by the Moon's shadow is called an eclipse. If the shadow entirely hides the sun, the eclipse is total; if it hides only a part, the eclipse is partial. If the round shadow of the Moon lies exactly over the sun's disk, but is too small to cover it entirely, a ring of the sun's surface will appear around the black disk of the Moon's shadow, and the eclipse is described as annular. The kind of eclipse depends upon the relative position of the sun, Moon and earth. Eclipses of the Moon are caused by the passage of the Moon through the earth's shadow. You will see at once that they can occur only when the earth is between the sun and Moon. That is, at the time of Full Moon.



(Fig. XVII.)

A total eclipse of the sun can be seen only on a small portion of the earth. In any one place it is seldom seen oftener than once in a lifetime. Eclipses never remain total longer than eight minutes, and seldom more than two or three minutes. But they are of such interest to scientists and others that whenever a total eclipse of the sun occurs, many people make long journeys to see it. Total eclipses of the Moon can be seen more frequently, for the earth's shadow is large, in comparison with the size of the Moon, and a total eclipse of the Moon often lasts several hours and can be seen wherever the Moon is visible. The Moon is, usually, not entirely hidden at its time of total eclipse, but shines with a dull, faint, copper-colored light. It is probably illuminated by light that passes near the earth and is deflected in passing through our atmosphere. The light becomes red, because it has to travel so far through the air, on account of its oblique direction. These rays fall on the surface of the Moon and are reflected back to us.

It is a peculiarity of our atmosphere that it gives a reddish hue to light that passes through a great deal of it. We see this at sunset, when the sun's rays appear red, because the sun is on the horizon and its rays have to pass through a great depth of air before they reach us.



(Fig. XVIII.)

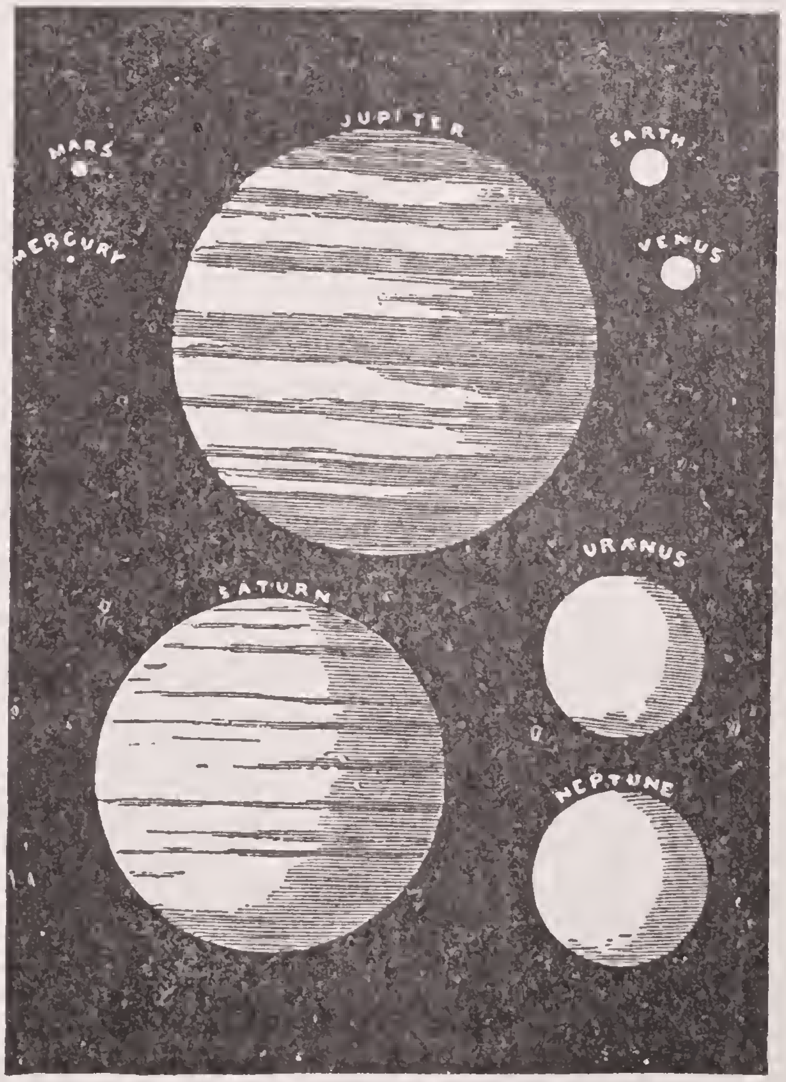
The time when eclipses will occur can be calculated with the greatest accuracy. There are at least two eclipses of the sun every year, and in some years there are as many as five. Figure XVIII. illustrates a total eclipse of the Moon. There are never more than two eclipses of the Moon in one year, but as they can be seen over so

much of the earth at one time, they can, perhaps, be seen at any one place more frequently than eclipses of the sun. You can find the times of eclipses given in reliable almanacs.

The next time that an eclipse occurs which is visible at your home, be sure to see it, for it is very interesting to watch the shadow growing over the sun or the Moon. In watching an eclipse of the sun, use a piece of smoked glass; for an eclipse of the Moon use opera glasses. If you are so fortunate as to have an opportunity to see a total eclipse of the sun, do not neglect it, for the greater part of mankind live and die without this privilege.

THE PLANETS

As HAS been said, there are eight large Planets, as well as many small ones. They all revolve about the sun, in the same direction. The names of the eight large ones are here given and it would be well for you to learn them, in the order given, which is the order of their distances from the sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. You will notice that two Planets are nearer the sun than the earth is. (Fig. XIX.)



(Fig. XIX.)

As stated before, there are two ways in which Planets can be told from fixed stars by the naked eye, namely, by their changes of place among the fixed stars, and by their shining steadily without twinkling. Mercury, Venus, Mars, Jupiter and Saturn are all bright objects in the heavens and naturally attracted the attention of early astronomers.

Long before the historical era began, it was known that these five bodies were different from the fixed stars, and they were given the names of Planets, or wandering stars. Uranus can with difficulty be seen with the naked eye, and to see Neptune and the smaller Planets or asteroids without a telescope is quite impossible. So, it is not strange that none of these bodies was discovered until quite recent times. Uranus was discovered accidentally in 1781 by Sir William Herschel, the greatest astronomer of his day.

Neptune was not discovered until 1846. It is smaller than some of the other Planets, being only eighteen times as large as the earth. As it is also very far distant from us, its light appears exceedingly faint. It might have remained unnoticed many years longer, if the only way of making its presence known had been by its light. You remember that, according to the law of gravitation, every particle of matter attracts every other particle. Uranus is near enough to Neptune to move a little irregularly in its orbit, on account of Neptune's attraction. Astronomers noticed this irregularity of Uranus and became convinced that it must be caused by the attraction of some unknown Planet. They were even able to tell in what part of the heavens this Planet must be, and with the aid of a telescope Neptune was found at once.

Mars is, in many respects, the most interesting of the Planets. As seen without the telescope, it looks like a bright star, but can be distinguished by its red color. Its orbit is of such shape that the planet is much nearer to us at some times than at others. Consequently, there are periods when it appears decidedly larger than it does at others, so that a better examination of it can be made with the telescope.

At these favorable times it is carefully studied by astronomers. Its atmosphere seems less dense than that of most of the Planets, and permits the discovery of many markings on the Planet itself. Around each pole appear white patches, which remind us of the ice fields around the earth's poles. There are bluish-gray patches, that are thought to be bodies of water, and orange-colored regions generally supposed to be land. If this view is correct, five-eighths of the surface of Mars is made up of land and three-eighths of water.

It is the orange-colored patches that give Mars its red color. The markings give evidence of changes of seasons, like those of the earth. The supposed ice caps vary in size according to the time of year, and the orange-colored portion takes on a more reddish hue, in what we suppose to be the summer. The Martian day is about half an hour longer than our own, or, to be more exact, Mars rotates on its axis once in twenty-four hours, thirty-seven minutes and twenty-three seconds.

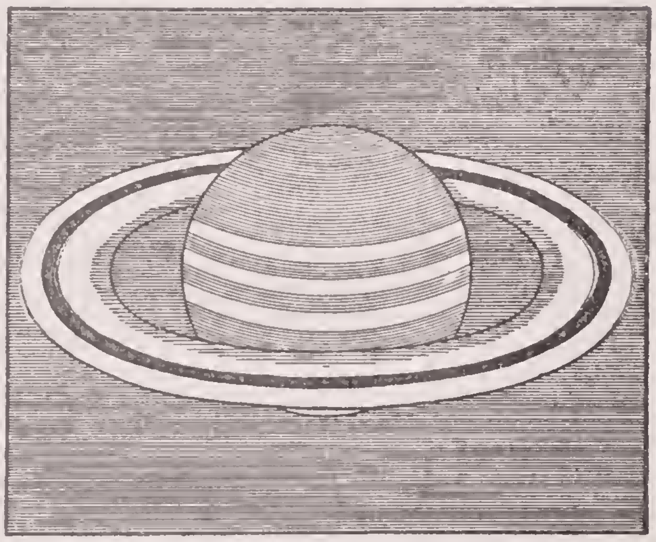
You will notice that there are many points of similarity between Mars and the earth. The question whether there are beings like men living upon Mars is one that has been much discussed. The only answer that can as yet be made is that we do not know, but there are many conditions that may make it possible. Perhaps proof will some day be discovered that intelligent beings exist there, but on the other hand, perhaps it will be found that there are reasons that make this impossible.

Although the two moons belonging to Mars are very small, they are so near that body that they would seem of large size if seen from it. Both revolve with great rapidity around the Planet. Instead of requiring twenty-eight days, as our moon does, to travel around in its orbit, the larger one makes the journey in a little more than thirty hours, while the smaller one goes once around its orbit in the short time of seven and one-half hours. As a result of this rapid motion, the smaller moon seems to rise in the West and set in the East, and its month is shorter than the Martian day.

Jupiter is the largest of the Planets; in fact, it is as large as all the rest of them united. As we see it with the naked eye, it appears less brilliant than Venus, which, though much smaller, is very much nearer the earth. When looked at through the telescope, beautiful markings appear on the Planet, the principal ones being known as belts. It is thought that these belts and other markings are in the Planet's atmosphere.

There is reason to think that Jupiter is not a cool, solid globe like the earth, but is a mass of hot, molten matter that is growing smaller and keeps itself hot by so doing. You will see, that in this, it seems to resemble the sun. It is not, however, thought to be hot enough to have light-giving powers of its own. Like the other Planets, it shines by reflected sunlight. The shadows of one or more of Jupiter's moons are frequently seen in the telescope, moving like dark spots across the face of the Planet.

Mars is interesting, because of its likeness to the earth, but Saturn is interesting, because it is so unlike every other object in the heavens. As seen with the naked eye, it is simply a bright object resembling a star. As seen with the telescope it is a wonderful body. It seems to be a globe like the other Planets, but it is surrounded by three rings of great width. (Fig. XX.)



(Fig. XX.)

It looks as though rings cut from immense sheets of paper have been slipped over the Planet and are kept in place by some unknown means so as to encircle, but not touch it. The rings are probably made up of numberless, small particles of matter, each revolving in a separate orbit around the Planet. Saturn has belt-like markings somewhat like those of Jupiter. It is nearly eight hundred times as large as the Earth, and is thought to be in much the same condition as Jupiter, though not quite so hot. Both Uranus and Neptune have a greenish appearance when seen through a telescope. Faint traces of belts appear on Uranus.

COMETS AND METEORS

Comets are objects that sometimes make a very startling appearance in the sky. They appear suddenly, and sometimes in a few days' time grow from a small object to one of astonishing size. There are a few Comets that travel in closed orbits, like the planets, and return regularly after a certain number of years. The greater number, however, make one visit to this part of the universe and then disappear forever. A Comet (Fig. XXI.) has a head or *nucleus*, which is surrounded by a sort of bright, cloud-like mass, which is called the *coma*. Spreading back from the coma is the *tail*. This tail is sometimes very short, and in some small Comets is absent altogether. In some cases, however, it is as long as the distance from the earth to the sun.

(Fig. XXI.)

In all the large Comets, the tail is the most noticeable feature. It is cloud-like in appearance and is often very brilliant. A Comet's tail has many peculiarities. One strange thing about it is that it is always turned away from the sun. Another strange thing is, that often no tail appears on the Comet until it is near the sun. The nearer the Comet comes to the sun, the larger its tail generally becomes, and it continues to point away from the sun.

The Comet moves faster as it approaches the sun, and as it passes that body the tail sweeps around with startling swiftness. Another wonderful thing is that the Comet's tail does not hide even the faint stars behind it. Stars that a passing cloud would prevent our seeing, shine plainly through the Comet's tail. Whatever the material of which this tail is composed, it is evidently thinner than the thinnest cloud. It is repelled by the sun, while the nucleus of the Comet is attracted by it.

The last Comet of great size appeared in 1882. Small Comets, which can be seen in telescopes, are very frequent, but those large enough to be seen without a telescope are less common. Perhaps once in ten years a bright one appears. Comets used to be looked upon as signs of disaster. To an ignorant people there would naturally be something terrifying in the sudden appearance of the gleaming brush

of a great Comet's tail. They are not now looked on with terror, but with great interest, as visitors from a distant part of the universe.

Meteors, or shooting stars, are so frequently seen that doubtless you are all familiar with their appearance. Usually we see a flash, as though a star were really shooting across the sky, and that is all. Sometimes we see a number of such objects in a short time. On several occasions, so many Meteors have appeared at one time that the appearance is well described as a *meteoric shower*. One of these beautiful showers occurred in November, 1833, and one in November, 1866. Another was looked for in November, 1899, but it did not take place then, neither did it come in 1900.

There are always numerous Meteors seen on the nights of November 12 and 13. The delayed shower may never come, or it may occur on these dates in November any time within a few years. It is well worth watching for, as it would be one of the most impressive spectacles of a lifetime.

Meteors are simply small masses of matter rushing through space so very swiftly that, as they enter our atmosphere, its resistance raises their temperature to such a degree that they immediately become red-hot. The smaller ones are at once burned up, and some of the larger ones fall to the ground. These are called Meteorites. Many of them have been seen to fall, and nearly every large museum has at least one specimen of this kind.

THE STAR-CLOCK

By DANIEL BATCHELLOR

THERE is always a charm for the human mind in marking off the divisions of time. The little child is greatly interested in the swing of the pendulum, and it is this which first interests him in the clock. At a later period he likes to trace the movement of the hands round the dial, and so he learns to "tell the time."

Although this soon becomes commonplace to him, there are other ways of telling the time, which never lose their charm. To one who has learned to trace the passage of time by means of the great star-clock, there is always a sense of awe and mystery, as the stars follow in their courses to tell him of the passing hours in the night, and of the progress of the seasons.

One serious drawback to a city life is that it shuts us in from the starry dome. The city child can have no adequate conception of

> "This brave o'erhanging firmament
> Fretted with golden fire."

He sees nothing but strips and patches of sky by day, and looking up at night through the glare of the city lights, he sees an occasional star dimly shining here or there. What can he know of the constellations, or of the silent sweep of the great star-clock? If all of our children could be brought up to recognize the stars as familiar friends, there would be less of littleness and fret in their lives, and less of nervous prostration later on.

No one can look up at the heavens, on a clear starry night, without a sense of awe; but to most persons there is also bewilderment. To them, the stars seem to be jumbled together in a confused mass. The first thing is to get order out of this chaos. They must learn to distinguish the more prominent stars, and to see their relation one to another. This may be considered as the anatomy of astronomy.

But it is still more important that they should get an idea of the movement of the stars, in order that they may see the universe as a living organism. This physiological aspect will make a stronger appeal to their vital sympathies.

Let them begin by seeing how the sun rises in the east and goes down in the west. They may then trace his journey across the sky, through the hours of the day. If possible, get a sun-dial whose shadow will mark off the time.

Get them to realize that the sun is a star, which is very large and bright, because it is much nearer to us than the other stars. It is our star. Then let them see, that, in like manner, the far off suns — which we call stars — rise in the east, pass overhead and go down in the west.

Now teach them that it is not the sun and stars which move, but ourselves, just as when we are riding in a train, the houses and trees seem to rush by us. The earth is a large ball spinning in space. It turns upon its own axis once every day. This is called its diurnal, or daily, motion. As the earth turns to the east the sun seems to rise in that quarter, and as it turns from the west the sun seems to set there.

But after awhile, the children will find that we do not always see the same stars in any particular part of the sky. For instance, if they look toward the south at a certain hour of the evening in the spring, and then look in the same direction and at the same hour in the summer, other stars will be found there. Again in the autumn they look there and find still other star groups. It seems, then, as if the stars on the horizon are passing before us like a great panorama. But here again "things are not what they seem." It is we who, on our earth-ball, are swinging around the sun. This is called the annual, or yearly, motion of the earth. In our long journey we come opposite the different star groups in succession.

There are twelve of these constellations, called the Signs of the Zodiac, which we pass in the annual round. Given in their successive

order, they are: 1, *Aries;* 2, *Taurus;* 3, *Gemini;* 4, *Cancer;* 5, *Leo;* 6, *Virgo;* 7, *Libra;* 8, *Scorpio;* 9, *Sagittarius;* 10, *Capricornus;* 11, *Aquarius;* 12, *Pisces.* Dr. Watt's jingle will serve both to interpret the Latin words, and to fix their order in the minds of the children:

"The *Ram*, the *Bull*, the Heavenly *Twins*,
And next the *Crab* the *Lion* shines;
The *Virgin* and the *Scales*,
The *Scorpion*, *Archer*, and the *Goat*,
The *Man that pours the Water out*,
And *Fish* with glittering tails."

When the twelve constellations have thus been memorized, the children will watch with interest for their panoramic unrollment in the heavens, as the seasons pass by.

In studying the great star-clock, the first thing necessary is to get our bearings. Fortunately, there is one star in the sky which holds its place, and forms a center around which the other stars perform their revolutions. It is called the *Pole Star*. This star is not quite stationary, but the circle in which it revolves is so small that it always seems to be in the same place. Whenever we look at that, we know that we are facing the north. Although the *Pole Star* is not by any means one of the brightest, it can be readily found, because there is no other bright star in its neighborhood.

Closely connected with the *Pole Star* is the most widely known of the star groups — the Dipper. In England it is better known as the Plough or Charles's Wain. These seven stars form the tail and loins of the *Great Bear* (Ursa Major).

The Dipper swings around the *Pole Star*, once every day, and in such a way that the two foremost stars are always pointing toward it. Hence they are called "The Pointers." Draw an imaginary line between these two stars, and then extend it about six times as far, and just a little back of this line you will find the *Pole Star*. (See Map 1.) In the United States and Canada, and in all countries north of 40° North Latitude, this constellation never sets, being too high up ever to go below the horizon.

(Map 1.)

See if the children can find the fainter companion which lies close to the star in the bend of the Dipper's handle. Looked at through an opera glass, or better a field glass, it stands out clearly. By the aid of a powerful telescope another beautiful star makes its appearance just above the companion star.

(Map 2.)

Measure the distance from the pointers to the *Pole Star*, and let the eye travel about as far beyond almost in a straight line until it comes to a beautiful constellation, in which five bright stars form an irregular W. This is *Cassiopeia*, about which more will be said presently. *Cassiopeia* and the *Great Bear* are always opposite each other as they revolve around the *Pole Star*. In the spring, when the *Great Bear* is high overhead, *Cassiopeia* is low down on the northern horizon. In the autumn, their relative position is reversed. (See Map 2.)

Now look on either side of the *Pole Star*, between these two constellations, and you will find two stars of the first magnitude. One is *Capella*, in the constellation of *Auriga* (The Charioteer), and the other is *Vega*, the chief star in *Lyra*. *Capella* is in the space toward which the *Great Bear* is moving, while *Vega* is in the opposite space from which the *Great Bear* is moving. They can also be at once distinguished by their color. *Vega* shines with a white light, whereas *Capella* sparkles with different colors. (See Map 2.)

(Map 3.)

Now that we have got our bearings with the *Pole Star* and its nearer attendants, it will be easy for us to get the relative positions of the other star groups.

There are some stars lying very near to the *Pole Star* which also revolve around it. These constitute the *Little Bear* (Ursa Minor). Indeed, the *Pole Star* is in the tip of the tail, so that the *Little Bear* swings around on his tail! (See Map 3.)

Let us return to *Cassiopeia*. This is one of a group of constellations sometimes called The Royal Family. They are associated with one of the finest of the Old-World stories.

Cassiopeia was the wife of Cepheus, king of Egypt. They had a beautiful daughter, named Andromeda. Her mother boasted that she was more beautiful than the Nereids, or Sea Nymphs, and Neptune, the sea god, was so angered by this presumption that he sent a sea monster named Cetus to devastate the country. To appease the anger of Neptune, Andromeda was chained to a rock in the Mediterranean Sea, and left for the monster to devour.

At this time there was a Greek hero named Perseus, who was believed to be the son of Jupiter. He was sent to slay the Gorgon Medusa, who was such a dreadful object, that whoever looked at her was turned into stone. Perseus avoided this fate by looking at her reflection in a mirror, while he struck the fatal blow.

He was returning in triumph, with the head of the Medusa, when he saw the beautiful maiden, Andromeda, chained to the rock. Cetus, the sea monster, was just foaming along through the water to devour her, when Perseus held aloft the Gorgon's head, and Cetus was turned into a rock. After this Perseus married the beautiful princess, amid great rejoicing at the Egyptian Court.

Now let us see how this story is illustrated in the star groups.

Cassiopeia is seated in her chair. Some day you may have a chance to look through a telescope, and see the beautiful diadem of stars around her head.

(Map 4.)

The two right hand stars of *Cassiopeia* point to the constellation of *Cepheus*. There is nothing very striking to the naked eye in this group,

but it contains some very interesting objects for telescopic study, among them the famous "garnet star." (See Map 4.)

(Map 5.)

Below the two left hand stars of *Cassiopeia* in the direction of *Capella* is the constellation of *Perseus*. This region is very rich in stars, and it lies right in the path of the *Milky Way*. On a clear night you will be able to see a small luminous cloud, which forms the apex of a triangle with the two left hand stars of *Cassiopeia*, already mentioned. This luminous cloud is somewhat brighter than the hazy light of the *Milky Way*. Looked at through a field glass, it is seen to have two centers, and when examined through a good telescope these are found to be star clusters of wonderful beauty. They are known as the *Great Double Cluster*. They furnish the jeweled hilt of *Perseus's* uplifted sword.

One other star in this constellation, well worth noting, is *Algol*, "the winking demon." It is considerably below the stars already pointed out, and forms a right angle with two other bright stars above it. The strange thing about *Algol* is, that it becomes very dim for a short time every sixty-nine hours. It is believed that *Algol* has a dark companion revolving around it, and that this dark body comes between the star and ourselves every third day, thus shutting off most of its light. (See Map 5.)

(Map 6.)

To the right of *Perseus*, and lying along below *Cassiopeia*, are three bright stars, at equal distances apart. These show *Andromeda* chained to the rock. Her feet stretch away toward *Perseus*, and the star in her head is also one of the four stars in the great square of *Pegasus*. (See Map 6.)

(Map 7.)

There is one object in this constellation which is noticeable. Take the middle star of the three, and then let the eye slowly travel up toward *Cassiopeia*. If the weather is clear, you will see a star which is less bright than the one we have left. Still let the eye move upward, and, if your sight is good, you will see a still fainter star. Now if you look through a field glass, this star will appear much more distinct and, a little off to the right, you will see a faint wisp of light. This is the famous nebula in *Andromeda*. When you know just where to look for it, you may see it with the naked eye, but that gives no hint of the real nature of this wonder of the heavens. The beautiful photograph of it shows that it is a system of worlds in the course of formation. (See Map 6.)

(Map 8.)

Some distance below *Perseus* and *Andromeda*, and separated from them by two groups to be noticed presently, is the constellation *Cetus*, the sea monster. It has eight bright stars in two unequal curves, and somewhat resembles a chair tipping backward. (See Map 7.)

And so by these constellations we see the old story pictured in the heavens.

(Map 9.)

Let us now take a rapid glance at the twelve constellations of the Zodiac which we pass in our annual journey around the sun.

THE TWELVE CONSTELLATIONS

1. *Aries* (The Ram)

THIS is the first of the Signs of the Zodiac. It comes between *Andromeda* and *Cetus*. If we look carefully in this region we shall see three stars in a crooked line, of which the two highest are the brightest. This is a winter constellation, visible in the evening, from October to February.

2. *Taurus* (The Bull)

The best-known group of stars in the constellation of the *Bull* is the *Pleiades*, which rises on the eastern horizon about the same time as *Capella*, but much farther to the right.

The *Pleiads* were seven daughters of Atlas, whom the gods placed among the stars. At first all seven were visible, but one faded away from some secret sorrow. You will recall Tennyson's famous lines:—

> «Many a night we saw the Pleiads, rising through the mellow shade,
> Glitter like a swarm of fireflies tangled in a silver braid.»

Looked at through a field glass, many beautiful stars can be seen in this cluster, and with a large telescope they can be counted by thousands. Curiously enough, in the photograph of them which has been taken recently, we see that all of the larger stars are enmeshed in nebulous matter, as if they are not yet completed, so that the poet was not far wrong when he spoke of them as « tangled in a silver braid.»

A second group in this constellation, which rises soon after the *Pleiades*, is the *Hyades*. It is a V-shaped cluster, and contains a bright, reddish star called *Aldebaran*. This is the angry eye of the *Bull*. There is a second bright star at some distance from the *Hyades*, in the direction of *Auriga*. This is at the tip of the *Bull's* upper horn, and a third star below is at the tip of the other horn. This constellation only shows the head of the *Bull*. (See Map 8.)

Closely associated with the foregoing constellation is *Orion*, although it does not lie within the path of the Zodiac. (See Map 9.) This is perhaps the

grandest of all the constellations. It rises after the *Bull*, and can easily be located, for *Capella* is half-way between the *Pole Star* and *Orion* in a straight line. When once recognized there will never be any trouble in knowing it again. There are four bright stars which mark the shoulders and limbs of the mighty hunter. The brightest of them are *Betelgeux* in the right shoulder, and *Rigel* in the left foot. The three bright stars in a line across the center form the belt of *Orion*, and the line of faint stars just below constitutes his sword. Look at this sword through a field glass, and you will see that some of the stars are enveloped in a hazy light. This is the most famous of the nebulæ. From its photograph we see that it is a world system forming, somewhat like the *Pleiades*, but not so far advanced.

(Map 10.)

The belt of *Orion* points downward on the left hand to *Sirius*, which is much the brightest of all the stars. This is sometimes called the *Dog Star*, because it lies in *Canis Major*, one of the hunting dogs of *Orion*. Not far from *Sirius* is *Procyon*, the *Lesser Dog Star*.

(Map 11.)

In the evenings of the late autumn, *Orion* rises in the east, and moves gradually overhead through the winter months until he slopes westward, after the setting sun, in springtime. Hence Tennyson was true to nature when, in describing the spring, he said: —

> "Many a night from yonder ivied casement, ere we went to rest,
> Did we look on great Orion sloping slowly to the west."

3. *Gemini* (The Twins)

Draw a line from *Aldebaran*, between the horns of the *Bull*, and you will come to two bright stars not far apart. The upper one is *Castor*, and the brighter one below is *Pollux*. These are the names of two youths famed in Roman mythology, who, at the battle of Lake Regillus, suddenly appeared on milk-white horses to aid the Romans, who were being worsted in the fight. After the battle they disappeared, and not till then did the Romans know that it was the Heavenly Twins themselves who had helped them.

(Map 12.)

The less conspicuous stars belonging to *Gemini* reach away in three parallel lines toward *Orion*. (See Map 10.) This constellation is seen in the evenings from December to May.

4. *Cancer* (The Crab)

This is not a conspicuous group, but it can be located by a triangle of faint stars, lying between *Procyon*, the *Lesser Dog Siar*, and *Regulus*, the brightest star in *Leo*. (See Map 11.)

5. *Leo* (The Lion)

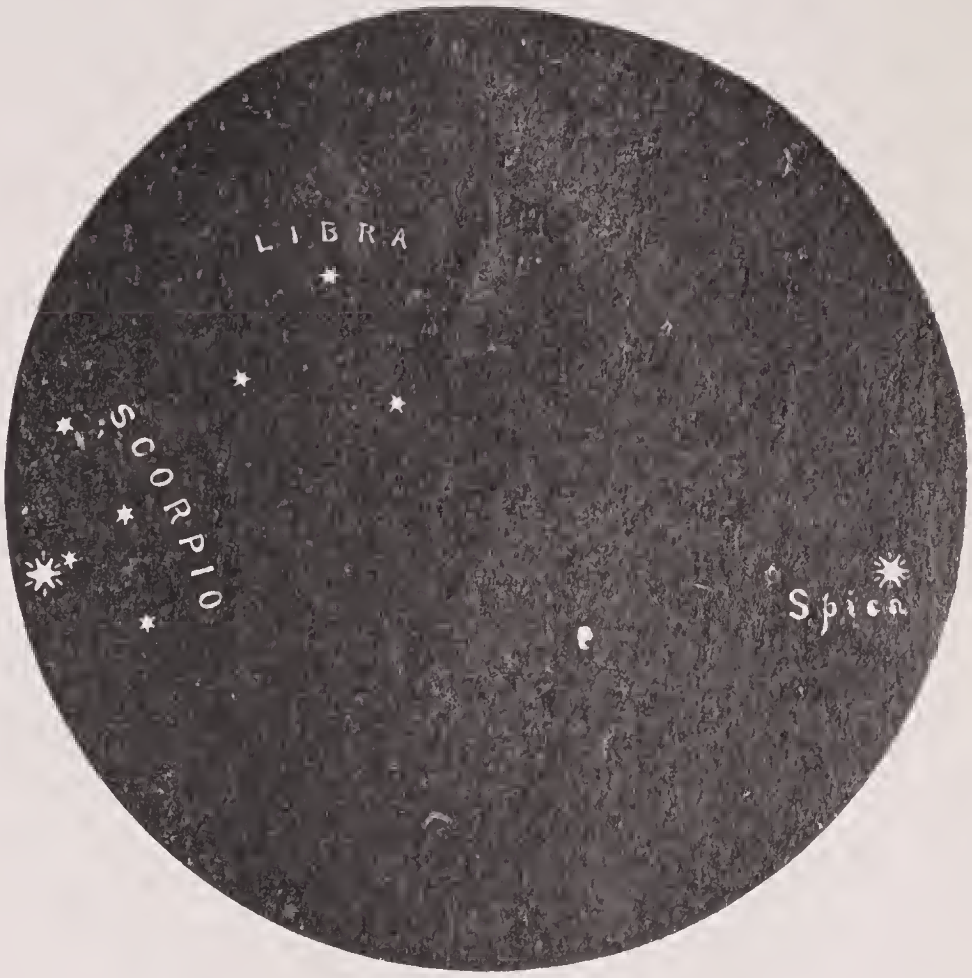
This fine constellation can be seen from October to the end of June. A straight line from the *Pole Star*, passing through the pointers in the Dipper, will lead directly to *Leo*. The front of the *Lion* is shaped like a sickle, of which the bright star *Regulus* forms the handle. Two stars behind the sickle represent the loins, and one star behind them, called *Denebola*, is in the tip of the tail. (See Map 12.)

(Map 13.)

From the center of the sickle the showers of November meteors seem to radiate. Hence they are called « Leonids.»

6. *Virgo* (The Virgin)

This is the next in order, and its place can be readily found by a bright star, named *Spica*, which shines with a white light, like *Vega* and *Sirius*. Above *Spica*, the chief stars of the *Virgin* branch out like the letter Y. (See Map 13.) *Virgo* can be seen to best advantage in the late spring and early summer.



(Map 14.)

7. *Libra* (The Scales)

This is not at all a conspicuous group. Let the eye travel along to the left of *Spica*, and not far from the head of the *Scorpion* you will see a triangle of faint stars. (See Map 14.)

(Map 15.)

8. *Scorpio* (The Scorpion)

This constellation at once attracts attention. It can be seen in June, rising on the southern horizon, and night after night it gets a little higher, until late in July, when its whole length can be seen for a little while, before it sinks again into the underworld. (See Map 15.)

Antares, in the shoulder of the *Scorpion*, is one of the most splendid of the stars. To get a better idea of the glory of its sparkle, you should look at it through a field glass, or a telescope. It seems as if Robert Browning must have had this star in mind when in his pretty little poem, « My Star,» he speaks of

"My star that dartles the red and the blue,"

especially as the path of Saturn lies just above *Antares*.

(Map 16.)

On the right of *Antares*, three bright stars in a curved line form the head of the *Scorpion*, while the body is well represented by a fine curve of stars below, and rather to the left, of *Antares*. If you have a field glass to trace down this curve, you will come across a beautiful pair of stars shining side by side like twin gems.

At the lower end of the body the tail curves sharply upward, and the sting or pincers is shown by two stars a little distance apart. Around this region a search with the field glass will reveal some very interesting star clusters and nebulæ which cannot be seen with the naked eye. It is at this point, too, that the *Milky Way* rises above our horizon and stretches away overhead to the northwest, when it sinks again into the southern hemisphere.

9. *Sagittarius* (The Archer)

Next in our star panorama comes the *Archer*. He is represented as having the head and shoulders of a man, and the body and legs of a horse. He is shooting an arrow at the heart of the *Scorpion*. (Map 16 will show the arrangement of these stars.) The four stars in a somewhat crooked line form the bow, and the small triangle to the right of them shows the point of the arrow. *Sagittarius* belongs to the late summer and early autumn.

(Map 17.)

10. *Capricornus* (The Goat)

Look to the left of *Sagittarius* until you see two stars close together with a line of fainter stars curving round to the left. (See Map 17.)

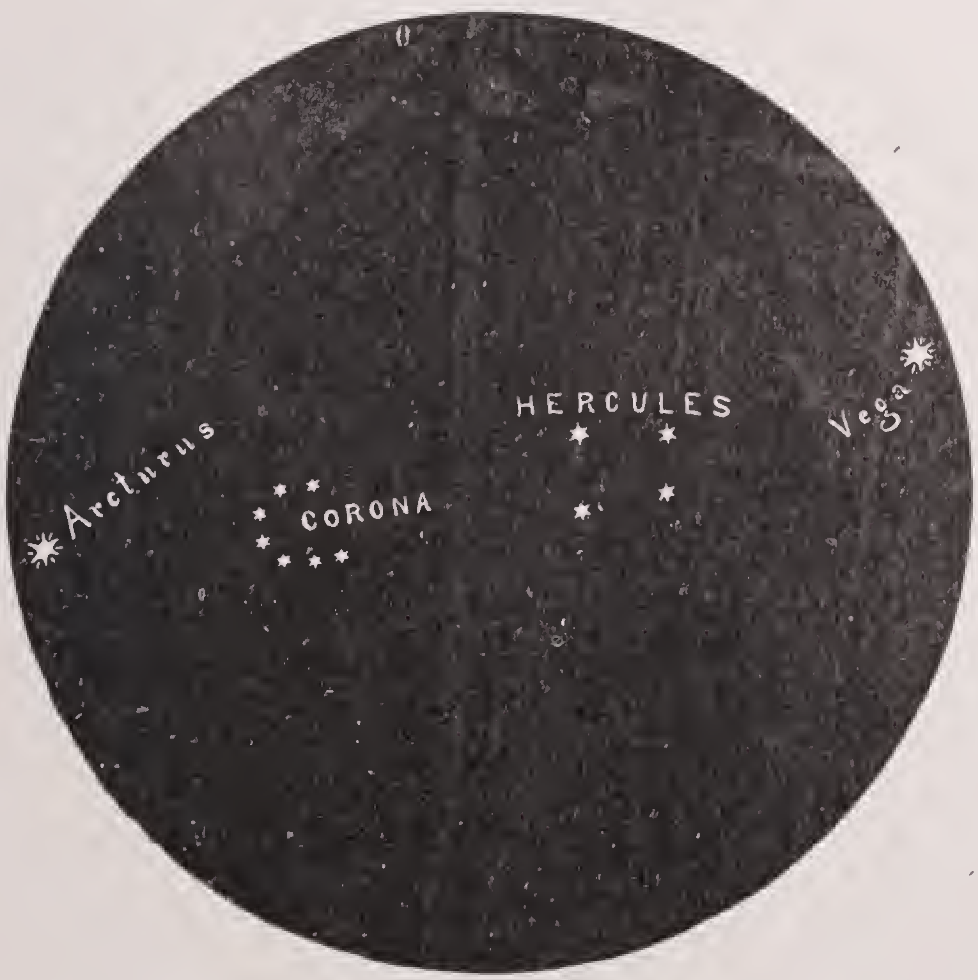
11. *Aquarius* (The Water Carrier)

Some distance above *Capricornus*, we find *Aquarius*. A zigzag line of four stars close together with another star some distance to the right and lower down, are the chief stars of this, the eleventh of the Zodiacal groups. (See Map 17.)

12. *Pisces* (The Fishes)

A long stream of faint stars, which represents the water being poured forth from the *Water Carrier's* urn, reaches down to a bright star in the south, called *Fomalhaut*. This is conspicuous, because there are no other bright stars about it. *Fomalhaut* is in the mouth of one of the fishes. This is the last of the Signs of the Zodiac, which brings us round again to the starting point in the *Ram*.

(Map 18.)

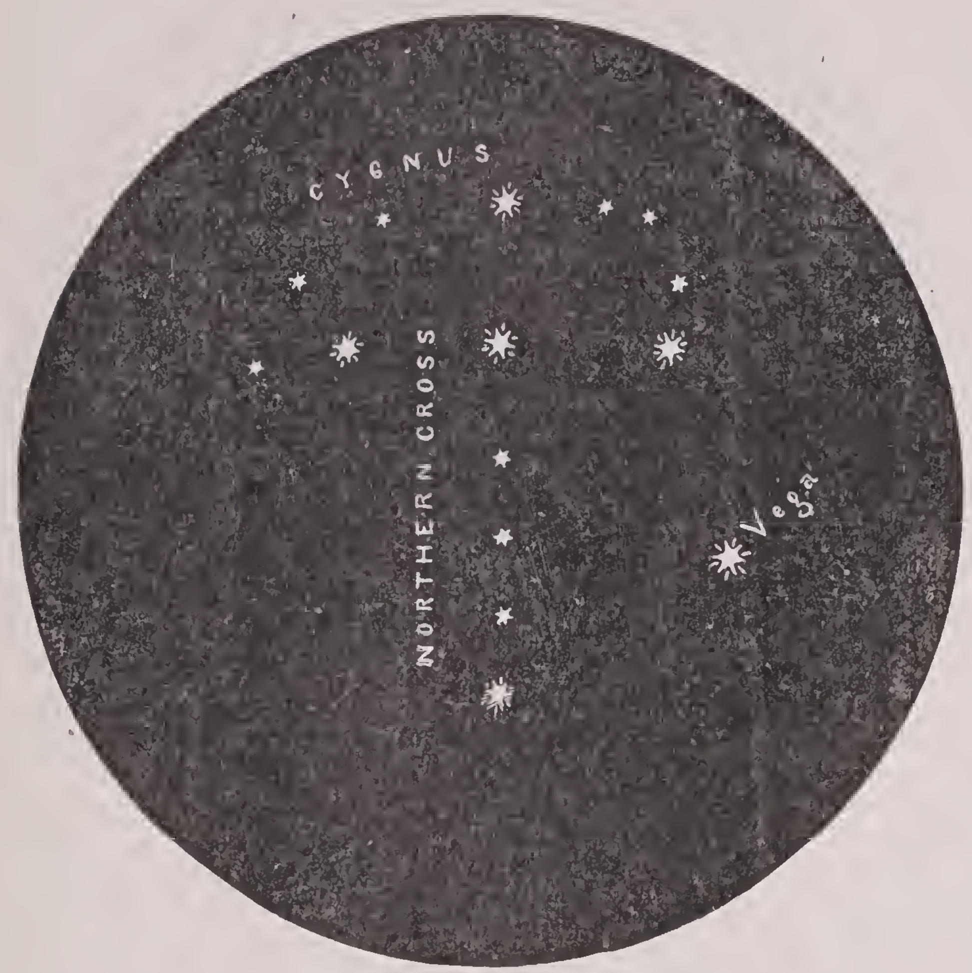


(Map 19.)

Before we leave the subject let us take one more look at the Dipper, but instead of turning to the *Pole Star* let us look about the same distance off from the handle, and at any time from April to September we shall see a brilliant star of an orange hue. Low down on the horizon it is sometimes almost red, but as it ascends, it loses some of its color. This star is named *Arcturus*. It is one of the giant suns of the Universe,

being thousands of times larger than our sun. It is the principal star in the constellation of Boötes the Bear driver, who is chasing the *Bear* around the *Pole Star*. (See Map 18.)

Draw an imaginary line from *Arcturus* to *Vega* and in passing over that line we cross two important constellations. About one third of the distance from *Arcturus*, we reach the *Corona Borealis*, the Northern Crown, and when we have traveled two thirds of the way to *Vega*, we come to an irregular square, something the shape of a pail or tub. (See Map 19.) This belongs to the constellation of *Hercules* — a most interesting character in mythology.



(Map 20.)

When we have reached *Vega* we are in the neighborhood of other interesting things. In one thing if you look at *Vega* through a field glass, you will probably see a pretty pair of stars just to the north of it. Then, too, you can find the Cross in the *Swan*, which lies just above and to the left of *Vega*. (See Map 20.) The Cross lies in the path of the *Milky Way*.

So we have traced some of the figures on the great star-clock. We have only just begun to take note of its many wonders; but enough has been shown to give us some little idea of what the poet meant by the "harmony of the spheres." We see a wonderful order and harmonious working running through all.

> "In reason's ear they all rejoice,
> And utter forth a glorious voice,
> Forever singing as they shine,
> 'The hand that made us is divine.'"

CHEMISTRY

CHEMISTRY

By GEORGE RAYWOOD DEVITT, M.A.

THIS science treats of the nature and composition of bodies and substances, and is grouped technically into two classes, inorganic chemistry, which relates to physical compounds, and, organic, which relates to animal and vegetable compounds. The science enters largely into many branches of art and industry, especially into medicine, metallurgy, agricultural, and other practical departments. In everything around us we see physical change, but we do not so readily see what chemical change produces under varying conditions and when subject to treatment by chemists. Many substances change, as we would say, naturally, when they decay, rust, burn, or ferment. There is a law, however, that governs matter, called "the law of conservation," which prevents matter from being destroyed, though, through chemical change, it may become quite different from the thing or substance it once was. An example of this is seen in gunpowder when it is made to explode and the product of the explosion is gas; a burning candle is another instance of change, when the wax, fat, or other material of which it is composed combines with the oxygen in the air to form water-vapor and carbon dioxide. As illustrations of the conservation of matter, the familiar instance of water changed to steam by heating or to ice by freezing, and the change in salt when dissolved in water, may be cited as instances of physical change, but not of chemical, for they can be returned again, by other processes, to their original condition or elements. In our day, 76 elements are recognized by chemists, many of which are rare. They are usually classed as metal and non-metallic, some of the latter being gaseous. The substances that are not elements are either mixtures or chemical compounds, containing two or more elements. Most substances commonly met with to-day are mixtures of chemical compounds, such as articles of food, materials of clothing, rocks, soils, paper, wood, glass, bricks, etc. The knowledge how to prepare and utilize these substances in physiological, technical, and industrial departments, is the work chiefly of modern chemistry. This knowledge on the part of our chemists, in organic and inorganic fields alike, is being wonderfully extended in our day by experiment test and research. The practical uses of this knowledge is seen especially in

products for commercial use, and in experiments, such as those for the liquefaction of gases, the production of liquid carbonic acid, etc., and in inorganic fields in researches into the toxic effect of solutions of certain acids and salts on plants, and the dyes derived from them.

Atomic Theory is, as its name implies, only a theory regarding the ultimate forms of matter, yet it is so supported by both physical and chemical facts, that it may be regarded as almost a fully established law. It is merely a hypothesis, but withal a very useful one, as it enables physicists and chemists to prove and explain many facts concerning matter which would otherwise be inexplicable. The atomic theory that a molecule of matter, which is the smallest particle of matter that can exist alone, and which is the ultimate form from the physicist's standpoint, is composed of smaller particles called atoms. These atoms are the smallest particles of matter which can enter into chemical combination. In this theory the hydrogen atom is taken as the standard, chiefly because hydrogen is the lightest substance known. The weight of each substance is compared with the weight of a like quantity of hydrogen, and this gives rise to the law of atomic weight. Thus it has been found that 35.4 parts of chlorine replace one part of hydrogen in a given compound, so that the atomic weight or the equivalent of chlorine is said to be 35.4. Again 16 parts of oxygen replace one part of hydrogen, so the atomic weight of oxygen is said to be 16. In arranging the elements in order of their atomic weight a remarkable regularity of succession is noticed. This gives rise to a Periodic Law, which states that the properties of an element are a function of its atomic weight.

Substances which are incapable of further subdivision or breaking up into other constituents are known in chemistry as elements. Chemical combination of the elements forms compounds. There are thousands of different substances in nature but these are all made up by the chemical combination of two or more elements. The number of elements is being constantly changed as the science of chemistry advances. Some substances which for years have been thought to be elements have proven to be compounds by the closer study of chemistry and by the aid of improved methods. Then again new elements are being discovered from time to time. At present there are between seventy and eighty elements known to chemists. Some of these are very rare. About a dozen of them go to make up most of the common familiar substances in nature. They go to make up the various kinds of matter in something the same way as the twenty-six letters of the alphabet go to make up all of the words in our language. And it is known that the same elements, say Hydrogen, Carbon and

Nitrogen, may be arranged in different ways to form several compounds wholly unlike one another; in much the same way as the three letters T, R and A, may, by different arrangement, go to form the words Art, Tar, and Rat. The list of elements as known is here given. The name of each element is followed by its symbol, which is not only a short-hand way of naming or of writing each, but is the symbol of a given quantity. When Al is written, there is meant by it not only Aluminum, but 26.9 parts of it by weight. It is also followed by the Atomic weight. By this is meant the weight of any quantity of this element compared with the same quantity of Hydrogen taken as a standard. The atomic weight is the relative density of the element, compared with Hydrogen taken as the standard, instead of water as is the case in physics.

		H-1	O-16			H-1	O-16
Aluminum	*Al*	26.9	27.1	Molybdenum	*Mo*	95.3	96
Antimony	*Sb*	119.1	120	Neodymium	*Nd*	142.5	143.6
Argon	*A*	39.6	39.9	Neon	*Ne*	19.9	20
Arsenic	*As*	74.4	75	Nickel	*Ni*	58.3	58.7
Barium	*Ba*	136.4	137.4	Nitrogen	*N*	13.93	14.04
Bismuth	*Bi*	206.9	208.5	Osmium	*Os*	189.6	191
Boron	*B*	10.9	11	Oxygen	*O*	15.88	16
Bromine	*Br*	79.36	79.96	Palladium	*Pd*	105.2	106
Cadmium	*Cd*	111.6	112.4	Phosphorus	*P*	30.77	31
Cæsium	*Cs*	132	133	Platinum	*Pt*	193.3	194.8
Calcium	*Ca*	39.7	40	Potassium	*K*	38.86	39.15
Carbon	*C*	11.91	12	Praseodymium	*Pr*	139.4	140.5
Cerium	*Ce*	139	140	Rhodium	*Rh*	102.2	103
Chlorine	*Cl*	35.18	35.45	Rubidium	*Rb*	84.76	85.4
Chromium	*Cr*	51.7	52.1	Ruthenium	*Ru*	100.9	101.7
Cobalt	*Co*	58.56	59	Samarium	*Sa*	148.9	150.
Columbium	*Cb*	93.3	94	Scandium	*Sc*	43.8	44.1
Copper	*Cu*	63.1	63.6	Selenium	*Se*	78.5	79.1
Erbium	*E*	164.8	166	Silicon	*Si*	28.2	28.4
Fluorine	*F*	18.9	19	Silver	*Ag*	107.12	107.93
Gadolinium	*Gd*	155	156	Sodium	*Na*	22.88	23.05
Gallium	*Ga*	69.5	70	Strontium	*Sr*	86.94	87.6
Germanium	*Ge*	71.5	72	Sulphur	*S*	31.83	32.06
Glucinum	*Gl*	9.03	9.1	Tantalum	*Ta*	181.6	183
Gold	*Au*	195.7	197.2	Tellurium	*Te*	126	127
Helium	*He*	4	4	Thallium	*Tl*	202.6	204.1
Hydrogen	*H*	1	1.01	Thorium	*Th*	230.8	232.5
Indium	*In*	113.1	114	Thulium	*Tu*	170	171
Iodine	*I*	125.9	126.85	Tin	*Sn*	117.6	118.5
Iridium	*Ir*	191.5	193	Titanium	*Ti*	47.7	48.1
Iron	*Fe*	55.6	56	Tungsten	*W*	182.6	184
Krypton	*Kr*	81.2	81.8	Uranium	*U*	237.7	239.5
Lanthanum	*La*	137	138	Vanadium	*V*	50.8	51.2
Lead	*Pb*	205.35	206.9	Xenon	*X*	127	128
Lithium	*Li*	6.98	7.03	Ytterbium	*Yt*	172	173
Magnesium	*Mg*	24.18	24.36	Yttrium	*Y*	88.3	89
Manganese	*Mn*	54.6	55	Zinc	*Zn*	64.9	65.4
Mercury	*Hg*	198.8	200.3	Zirconium	*Zr*	90	90.7

When two or more elements unite to form a substance differing in its properties from the constituent elements, a chemical change has been brought about. If copper filings and powdered sulphur be

mixed intimately, and the result be examined by a microscope, the particles of copper and of sulphur may be plainly seen lying side by side, although to the naked eye the color of the mixture is unlike either the copper or the sulphur. This is only a mechanical mixture. But if heat be applied to the mixture, it will be found upon examination that no copper and no sulphur can be seen. A new substance has been found, totally unlike either of the elements. Here a chemical change has been brought about. The air is only a mechanical mixture of several gases, while water is a chemical mixture of two gases, Hydrogen and Oxygen.

AIR

Before learning about the individual gases of which air is composed, something should be known of the quantity of air that surrounds the earth, and of its properties or qualities. It is, perhaps, generally known that enveloping the earth is a layer of air fifty or more miles in thickness. Just how thick this layer is we do not know, but we do know that it extends many miles from the earth. You may assure yourselves of this in a very simple manner by watching the shooting stars that may be seen on any clear night. These are nothing but masses of rocks that give off light only when they have been made red-hot by friction with the air in their rapid flight. The fact that we often see these stars while they are still many miles from the earth proves to us that the air through which they are passing extends to that height.

Air is very light, so light that it seems to have no weight at all; but, if you will think a minute you will see that it must have some weight, because birds fly in it and balloons can be made to float through it. It has been found that one hundred cubic inches of air at the sea level weighs, under ordinary conditions, about thirty-one grains. This seems a very small weight, but when we remember the thickness of the atmospheric envelope over the earth we see that it must press quite heavily upon the earth's surface. There is a very simple instrument called a barometer, which is used for measuring the amount of this pressure. The name means pressure-measure.

Another striking feature of air is its elasticity, and this explains something that is noticed by all mountain climbers. On a high mountain, it is difficult to get enough air to the lungs, though one breathes rapidly and deeply. The reason is, that the air at the foot of the mountain is compressed by the weight of that above it, and consequently the lungs can hold more of it than of the air on the

mountain top, which has less weight resting upon it and is, therefore, not so much compressed. On account of the ease with which it is compressed, we find that more than half of all the envelope of air that surrounds the earth is within three miles of the surface.

When air is chemically analyzed it is found to consist of a number of substances mingled together but not chemically united. These include *nitrogen*, *oxygen*, *argon*, *carbonic acid gas*, *water-vapor*, *ozone*, *nitric acid*, *ammonia*, and *dust*.

Oxygen is the most important of these constituents, for it is the part that is necessary to support life. Yet, notwithstanding its importance, it forms only about one-fifth of the entire bulk of the atmosphere.

Oxygen is a very interesting substance and many striking experiments may be performed with it. If a lighted candle is thrust into a vessel filled with oxygen, it burns very much more rapidly and brilliantly than in air. A piece of wood with a mere spark on it bursts into flame and burns brightly when thrust into oxygen, and some things that will not burn at all in air, can be made to burn very rapidly in oxygen. For example, if a piece of clock spring be dipped in melted sulphur and then put into a jar of oxygen, after the sulphur has been set on fire, the steel spring will take fire and burn fiercely. The heat produced is so great that drops of molten steel form at the end of the spring, and falling on the bottom of the jar, melt the surface of the glass where they strike.

The other two substances found in pure air, nitrogen and argon, are very much alike. They make up the remaining four-fifths of the air, and are very different from oxygen in nearly every respect.

Nitrogen and argon resemble oxygen in being colorless, odorless, and tasteless gases; and they are of nearly the same weight as oxygen, argon being a little heavier and nitrogen a little lighter; but here the similarity ends. Oxygen is what we call a very active substance. As we have seen, it causes things to burn very much more rapidly in it than in air. Nitrogen and argon, on the contrary, put out fire. If a lighted candle is put into a jar of nitrogen or argon its flame will be extinguished as quickly as if put into water.

We must now consider the impurities found in air. Of these the most important is carbonic acid gas, or, as it is frequently called, carbon dioxide. It is always produced when wood or coal is burned, and is, of course, constantly being poured out of chimneys. It is also produced in our lungs and we give off some of it when we breathe. It is colorless, like the gases found in pure air, has no odor or taste, and is considerably heavier that oxygen or nitrogen. In its other properties it is much more like nitrogen than oxygen, for when a

candle is put into it the flame is extinguished at once. To find out whether air contains carbonic acid gas, it is only necessary to force it through a little lime water, in a glass vessel, and watch what change takes place in the water. Fresh lime water is as clear as pure water; but after forcing air containing carbonic acid through it, it becomes turbid and milky. If the turbid water is allowed to stand for a time, a white powder will settle to the bottom, and if we examine this powder, we find it to be very much the same thing as chalk. While it is true that air generally contains only a very small portion of carbonic acid gas, there are some places in which it is present in such large quantities as to render the air unfit for breathing. The air at the bottom of deep mines and old wells often has an unusually large proportion of this gas, which, because of its great weight, accumulates at the bottom, and remains confined there. The presence of a dangerous quantity of the gas in such places may be detected by lowering a candle into it.

In some parts of the world large quantities of carbonic acid gas are constantly issuing from openings of the earth's surface. Two such places are the famous Poison Valley of Java and the Grotto del Cane near Naples, in Italy. The former is a small valley about half a mile around and about thirty-five feet deep, in which the air is so loaded with carbonic acid gas, that animals entering it are killed in a few minutes. Even birds that fly over the valley are overcome if they do not rise high above it. The Grotto del Cane, or Grotto of the Dog, is a small cavern in the crater of a volcano. A stream of carbonic acid gas flows constantly into the grotto, but the level of the gas does not reach the height of a man's mouth. When the same air is breathed over and over again, the quantity of carbonic acid in it is increased so much, that it may become as deadly as the air in the Poison Valley.

Two other gases that may generally be found in the air are *ozone* and *ammonia*. The first is merely a form of oxygen that is produced by the passage of lightning through the air. After severe thunderstorms, it is said to be present, sometimes, in sufficient proportion to give to the air a slightly pungent odor. It is more active chemically than is the ordinary form of oxygen, and, consequently, has a stimulating effect upon animals.

Ammonia, or hartshorn, as it is sometimes called, from the fact that it was formerly obtained by distilling the horns of harts, or deer, is almost always present in the air in small quantities. It is produced chiefly by the decay of animal and vegetable matter, especially the former. Though present in the air in very small quantities, it is of much value to the plant world because it contains

nitrogen in a form in which it can be readily absorbed by plants. All plants contain some nitrogen, which is essential to their growth, but the greater part of the nitrogen in the air is not in such form that it can be absorbed by them. They must obtain their supply from the soil, which usually contains some nitrogen in a form that may be taken up by plants, and from the ammonia in the air. The latter is not taken directly out of the air by the plants, but the rains falling through the air absorb the ammonia and carry it to the soil, from which it is taken up into the plants by their roots.

Besides the gases that have been mentioned, there is present in the air, at all times, a small quantity of water-vapor, which is, in many ways, as important to mankind as is the oxygen itself. The quantity of water in the air is not always the same. As a rule, the quantity is greater in warm air than in cold, and is less over land than over water. Frequently the air feels damp in cold weather, and dry in hot weather, and it is natural to suppose that there is more vapor in the air on a damp day than on a dry one. This, however, is not always true. There is usually more moisture in the air on a warm summer day than on a cold day in winter, though the winter day may seem much more moist. You will be able to understand why this is so by comparing the air to a sponge. If we fill a sponge with water, and squeeze it gently, a little water will be forced out of it. If we then remove the pressure, the sponge will swell again, and will appear dry on the surface, but there will still be water in it, and on being squeezed harder than before it will again become moist on the surface and more water will be forced out of it. Now cold has an effect upon moisture-laden air very much like that of pressure on the sponge. When the air cools, some of the moisture is forced out of it, and the air seems damp. When it warms again, the air seems dry, though there is still water-vapor in it. It seems dry because it can absorb more water-vapor, just as the sponge seems dry after you cease to squeeze it, though it still contains water. From this we see that the air does not always seem moist, when there is much water-vapor in it, nor dry when there is only a little. It feels moist when there is as much water-vapor present as it can hold, and dry when it can hold more than it already has. And we also see, that, in hot weather, the air can hold much more moisture than it can in cold weather, so that whether the air feels dry or moist, there is generally much more water-vapor in it, in hot weather, than in cold.

It is easy to see that, over water, the air naturally takes up more moisture, than over land, because there is so much more water there to be transformed into vapor. Over the surface of seas, lakes, and

rivers, water is continually being converted into vapor by the process of *evaporation*, and this vapor is absorbed by the air.

Let us now consider the solid particles floating in the air, the dust that is seen dancing in the path of the sunbeam. Whenever we examine the air, these small particles are found, even on the tops of mountains, and at points so high above the earth that they have been reached only by balloons. Of course, there is very much less dust high above the earth than near the surface, where the winds are constantly stirring up the loose soil, and throwing into the air small particles of every kind. In cities, where factory chimneys are continually pouring out clouds of smoke, and the people and vehicles are constantly disturbing the dust of the streets, the air always contains more dust than does the air of the country.

In order that we may breathe the air, the oxygen in it has been mixed with four times as much nitrogen and argon, which must be inhaled with the oxygen, though they have no more effect on the body than the water you take with a strong medicine to weaken it. The oxygen, however, has a very important effect upon the body, and if we compare the air we exhale with that we inhale we find considerably less oxygen in the former than in the latter. In place of the oxygen, the air has received carbonic acid gas. It may seem very strange to say that there is burning going on in the body, but that is very nearly what takes place. The chief difference from coal-burning is that in the body the process goes on so slowly that it does not make the body very hot; but when we set fire to coal, the process is much more rapid and a large amount of heat is produced, in a short time, so that the coal becomes very hot. The products of breathing and coal-burning are the same, carbonic acid gas being the chief one. When coal is burned it disappears, together with some of the oxygen of the air, and in their stead we have carbonic acid gas. When a breath is taken some of the material of the body disappears, as does some of the oxygen of the air, and in place of them carbonic acid gas is found. If we could weigh the coal burned and the oxygen that disappears in the burning of it, and could then weigh the carbonic acid gas that is produced in the burning, we should find that the latter weighs just as much as the coal and the oxygen together. So, too, if we could weigh the oxygen that disappears from the air we breathe and also find the weight of the material taken from our bodies, by breathing, we should find that the two together weigh just as much as the carbonic acid gas given off in our breath. In neither case is anything absolutely destroyed; the substances resulting from the change, weigh just as much as those that took part in it.

Having learned that a quantity of oxygen disappears every time we take a breath, and every time we build a fire, it would seem that in the thousands of years during which men and animals have been living on the earth, all the oxygen would have been exhausted and nothing left in its place but carbonic acid gas. That, however, is impossible, as the carbonic acid gas is used up almost as fast as it is produced and the oxygen is returned to the air in its stead.

All trees and plants, from the great redwood trees of California to the smallest flowers that dot the fields, need carbonic acid gas to keep them alive and to make them grow. Their leaves have the power when the sun shines on them to take up carbonic acid from the air and to return oxygen in exchange. In this way you see that the balance is kept just as it should be. The oxygen needed by animals of all kinds is furnished by the plants, and the carbonic acid required by plants is thrown off in the breath of animals.

WATER

The substance that is next to air in abundance, and in importance to mankind, is water. It covers three-fourths of the surface of the earth, with a layer of varying depth. It is present, as we have seen, in the air itself; and it forms three-fourths of the weight of all living animals and plants. Its removal would destroy all animal and plant life, as surely as the removal of air, though not so quickly.

Pure water is made up of only two substances, and, as in the case of air, it was not until a little more than one hundred years ago that water was found to be divisible into substances of different kinds. The two substances that are found in pure water are not liquids, as you might imagine, but are gases — oxygen and hydrogen.

Hydrogen is in some respects like oxygen, nitrogen, and carbonic acid gas. It has no odor, no color, and no flavor. Were it mixed with air you could not detect it by sight, smell, or taste. It has two properties, however, that are very different from those of any of the three gases mentioned. It is much lighter than any of them, being, in fact, the lightest of all known substances; and it will take fire and burn in air, when a lighted match is brought into contact with it.

Hydrogen is found in many substances besides water, and it is generally obtained from some of the others, because it is rather difficult and expensive to obtain it from water. Those most generally used are sour substances, called acids, of which vinegar is a good example. All acids contain hydrogen, together with other substances, of which oxygen is often one, and they have the property of giving

up the hydrogen they contain when they are brought into contact with certain metals. If, for example, you put some sulphuric acid into a bottle, and after adding to it three or four times as much water as there is acid, you drop in some pieces of zinc, you can see the zinc slowly dissolve, and hundreds of bubbles of hydrogen gas rise rapidly through the diluted acid. These seem to be coming out of the zinc, but they really come out of the acid, and the zinc takes their place as it disappears.

If, after all the air in the bottle has been replaced by hydrogen, the latter is allowed to escape through a tube, it may be burned, like the ordinary gas you have seen used for lighting purposes. The flame will not be bright and white, however, but will be a very pale blue, and will give very little light. It is so pale, that a small hydrogen flame cannot be seen in bright light at all. If a glass vessel is now held bottom upward over the flame for a while, its inside will be seen to become covered with moisture, and if the burning is kept up for some time drops of water will form on the sides of the vessel and trickle down to the edges. These are formed by the chemical combination of the hydrogen with the oxygen of the air during the burning. If you have arranged the apparatus in such a way that none of the water could escape, and that the quantity of hydrogen burned, and the quantity of oxygen required to burn it, could be measured, it will be found that the water formed in the burning weighed just as much as the oxygen and hydrogen together.

Another method of showing that water is composed of hydrogen and oxygen is to pass a current of electricity through some of that liquid contained in a suitable vessel. When this is done bubbles of hydrogen and oxygen will be formed and will rise through the water. These may be collected separately, and the two gases being measured, it will be found that there is just twice as much hydrogen as oxygen given off; that is, for every pint of oxygen given off there would be two pints of hydrogen. But when the weights of the oxygen and hydrogen are compared, it will be found that one pint of oxygen weighs eight times as much as the two pints of hydrogen; in other words, that oxygen is just sixteen times as heavy as hydrogen. We see therefore, that in water there are eight parts, by weight, of oxygen, to one part, by weight, of hydrogen; but that there are two parts, by volume, of hydrogen, to one of oxygen.

There are two metals, *sodium* and *potassium*, that have the property, when thrown upon water, of decomposing it and setting a part of the hydrogen free. Both of these metals are lighter than water, and they float upon its surface until they have completely dissolved. The action of the potassium is so vigorous that the hydrogen set free

takes fire and burns around the floating piece of metal. The sodium acts less violently, and the hydrogen does not take fire spontaneously, but will burn when lighted. Both metals combine chemically with the oxygen and half of the hydrogen of the water, forming compounds called *sodium* and *potassium hydrate*, about which more will be said later. The presence of these compounds in the water gives it a peculiar slippery, soapy feeling.

Having found what water is composed of, and how it may be produced, let us now examine into the great change that takes place when oxygen and hydrogen are caused to unite and form water. When these two gases are simply mixed together, no change takes place in them; but if you set fire to the mixture, an explosion occurs, and a small quantity of water is formed in place of a considerable quantity of gas. The change that has taken place is called chemical combination, and the product, water, is called a chemical compound. A chemical compound is in many respects different from a mere mixture of substances. In a mixture the substances may be present in any proportion, and the mixture will always have the properties of its various constituents. A compound, however, is always composed of the same substances in exactly the same relative proportions, and the properties of a compound are often entirely different from those of the substances of which it is composed. Air is a mixture, and we may add more oxygen or remove some from it at will, without producing any very great change in its properties. But in water, the proportions of oxygen and hydrogen cannot be changed a particle. If the oxygen and hydrogen are not mixed in the exact proportions of one volume of oxygen to two of hydrogen, some of one or the other will be left free. In its properties water bears no more resemblance to the gases that compose it than to many substances with which it has no connection. It is not light and gaseous, and it will neither burn like hydrogen nor support combustion like oxygen. On the contrary it puts out fire instantly, notwithstanding the fact that eight-ninths of its weight is oxygen, the best of all supporters of combustion.

Water, in common with other fluids, possesses a peculiar property which causes it to *seek its own level*, as we say. We all know it is impossible to make the surface of a body of water remain uneven for any considerable length of time, or to make a mound of it, as we can of sand or earth. If water is stirred, it becomes very rough for the time, but as soon as the stirring ceases the water begins to grow quieter, and if there is no further cause of agitation, the perfect level will soon be restored. This law may also be illustrated by placing water in a vessel that has across it a division through which

the water can pass at some point. If the water is poured so that it stands higher in one part than the other, the water will run through from the higher to the lower side until both reach the same level.

At ordinary temperatures water is a colorless, or very slightly bluish, liquid, a cubic foot of which weighs about sixty-two and one-half pounds. When it is cooled it contracts slightly until it reaches the temperature of 39° Fahrenheit, at which point it begins to expand a little, and continues to do so until it reaches 32° Fahrenheit. This is called the *freezing point*, because it is the temperature at which the water freezes; that is, it is changed to a crystalline solid called *ice*. The change to ice is accompanied by a still greater expansion. amounting to an increase of one-ninth of the volume of the water. The increase is explained by the change of water to the crystalline form, in which its particles take up more room than they did in the liquid. The crystals in ice cannot often be seen in a solid cake of it, but they may be observed in water just as it freezes, especially if the water has remained quiescent while cooling to the freezing point, and is then suddenly disturbed. The water under such circumstances suddenly becomes filled with little sharp-pointed crystals, which soon unite into a solid mass. The crystals formed in this way, however, are by no means so beautiful and delicate as those found in snowflakes. When large flakes of snow are caught on dark woolen cloth they can be seen to consist of hexagonal (six-pointed) crystals of great variety and beauty.

The reason why water ceases to contract when cooled to 39° Fahrenheit, and then expands is not known, but that it does so, is a very useful provision of nature. If water continued to contract until the freezing point was reached, the coldest water would be the heaviest and would, of course, sink to the bottom and begin to freeze there. The process would gradually extend upward and finally reach the top. In this way lakes and rivers would be frozen solid. Under existing conditions, however, this is impossible, for the water that is cold enough to freeze is always found at the top and the formation of ice must begin there.

An interesting fact about the formation of ice may be illustrated, if a heavy glass bottle is filled with water, corked tightly, and left out of doors on a cold night. In the morning the bottle will be found broken by the expansion of the water in freezing. A similar result may be brought about if the water is put into stone jugs or even a hollow cast-iron or steel shell. This will give some idea of the great force with which water expands in freezing.

The changes brought about by heating water are also interesting, and, perhaps, even more important as regards useful application than

those produced by cooling it. When heated, it expands very gradually until it reaches a temperature of 212° Fahrenheit, when it boils and is converted into *steam*. All the water in a vessel is not suddenly converted into steam, as soon as the temperature reaches 212° Fahrenheit, however. If that were to take place, an explosion would be produced, for the steam formed from a quantity of water takes up many times as much space as the water itself, and steam expands with great force. When water boils in an open vessel it is gradually converted into steam, which escapes into the air and is *condensed*, or in other words, is changed to water again. It is this water which forms the white cloud that rises from a kettle, or escapes from the cylinders of a locomotive engine. The steam itself is an invisible gas, while the cloud over the kettle is composed of small drops of water.

It is not necessary to boil water, however, in order to convert it into a gas, or vapor. If a vessel of water is simply left exposed to the air the water will gradually disappear, or, as we say, "dry up." When water disappears in this way it is said to *evaporate*, by which is meant that it has been converted into a vapor, and has become mixed with the air. Evaporation goes on all the time and at any temperature, but it takes place more rapidly at high temperatures than at low ones, and in dry air than in moist. Winds also aid in evaporation, because they remove the water vapor as soon as it is formed and bring dry air into contact with the surface of the water. When the air is dry, and a strong wind is blowing, snow and ice are said to evaporate without melting, and it is certainly true that frozen clothes will dry when exposed to this kind of weather. It is not quite true, however, that snow and ice evaporate without melting. Melting really occurs, but the water formed is evaporated as soon as it forms, and consequently it is not seen.

The process of evaporation plays a very important part in the economy of nature, as has already been hinted in what was said of air. Vast quantities of water are continually evaporating over the surface of the earth, and the vapor thus formed, being lighter than air, rises until it reaches a level at which it is cooled so much, that the air can no longer hold it. The vapor then condenses into very small drops, which unite to form clouds, and, when the air cools a little more, these drops unite to form large ones, which are too heavy to float in the air, and therefore fall to the ground as rain.

But the water-vapor that is condensed in the upper levels of the air does not always reach the earth in the form of rain. When the vapor is suddenly chilled and the temperature reduced to 32° Fahrenheit, raindrops cannot form. The small drops of water in the clouds

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freeze before they have time to unite into larger drops, and snowflakes are formed instead. If falling raindrops pass through a layer of very cold air they may freeze and fall to the earth as lumps of ice, called *hail*.

Of the water that is formed from the vapor in the air and falls upon the earth as rain, snow, or hail, a part soaks into the soil, some remains on the surface and evaporates, and the rest flows away in streams. The streams unite to form larger ones, and these finally reach the sea, from which most of the water-vapor in the air comes. Thus you see that the water on the earth is constantly making a round, or cycle.

Some of the water that soaks into the ground is taken up by the roots of plants, but the greater part of it continues to sink down into the earth until it reaches a layer of some material that it cannot penetrate, such, for example, as clay or granite. It then flows slowly along the surface of this layer, or stratum, and if it reaches a part of the country that is lower than the plane of the stratum it may come to the surface as a spring.

If, as is often the case, the impervious layer is lower in some parts than in others, the water travels along until it reaches one of these lower places, where it accumulates. Deposits of this kind are often the spring or source of the water supply in wells that are sunk into the ground.

There are some wells, from which the water flows naturally above the surface of the earth. In the earth's structure there are layers of different substances. Some of these are so formed that water can pass through them, and these are said to be *pervious*. Those through which it cannot pass are said to be *impervious*. A pervious layer, such as sand or sandstone, often lies between two impervious layers, like clay or granite. If these layers reach the earth's surface somewhere, and there is an opening in the upper impervious one, a basin is formed, from which water passes into the pervious substance. The water flows on through this substance to the lowest point, or lowest level, of the lower impervious layer, and accumulates in this lower basin. If a well is now opened, from a point on the surface at or below the level of the basin which supplies the water, down through the upper impervious layer into the lower basin, the water at once rises to seek its own level. In doing this it may flow to the mouth of the well, or may even overflow, in its effort to reach the level of the basin from which it first came.

Occasionally it happens that a basin is found on the surface of the earth in which a layer of pervious earth, such as sandstone, lies between two impervious layers. If the edges of the pervious layer

reach the surface, water will soak into it and sink until it reaches the bottom of the basin. It cannot rise through the impervious layer, but when a well is sunk through the impervious layer the water will rise in it, and if the edges of the pervious layer are higher than the surface of the ground at the point where the well is sunk, the water will flow out of the well. Wells from which the water flows are known as *Artesian wells*, because they were first found in the province of Artois in France. Artesian wells have been sunk to a depth of nearly three thousand feet.

The water that flows from springs is sometimes quite cold, more frequently it is cool, and occasionally it is boiling hot. The temperature of the water of springs is determined by the temperature of the rocks with which it has been in contact, and since it is known that in some regions heated rocks lie very near the surface of the earth, it is not surprising that some springs yield hot water. There is a kind of hot spring from which the water does not flow steadily, but spouts forth at intervals with considerable violence, often throwing a column of water thirty or forty feet into the air. Springs of this kind are called *geysers*. Geysers are usually found in volcanic regions. The most famous geysers in the world are found in Iceland and in the Yellowstone National Park in Wyoming.

We all know how necessary water is to the support of animal and plant life; but we seldom notice how perfectly it is adapted to its important uses, and how much it contributes to our comfort. Even the absence of taste and smell in water are important. While sweet, fragrant odors are pleasant at times, and we enjoy pleasant flavors in food and drink, there is no taste or odor of which people do not tire, and there is none that would be pleasing to all mankind.

Another property that makes water of great value to both men and animals is its cooling property. No other liquid can take up so much heat as an equal weight of water. When taken into a heated mouth or stomach it cools it more than the same quantity of any other substance could, and when it evaporates on the skin in the form of perspiration the same cooling effect is felt.

Perhaps the most important property of water is the readiness with which it will mix with liquids and dissolve solids. The great majority of all liquids mix readily with water, and there are very few solid substances that are not dissolved to some extent by it. Of course, there are some that are only slightly soluble in it, but many dissolve very readily, and some, like limestone and glass, which seem quite insoluble, are really dissolved in very small quantities.

On account of this property water is never found perfectly pure in nature. That which falls in rain absorbs impurities from the air;

that which rises in springs dissolves more or less of the rocks and soil over which it passes; and that which is found in rivers contains so many of the impurities washed off the land, that they can often be plainly seen. The quantity and kind of impurities found in river water depend upon the kind of soil over which the river flows and the strength of its current. Those streams that flow over rocky beds are usually very clear, regardless of the speed of the current; those that have banks and beds of loose, light soil always carry more or less of it with them, and the stronger the current the more they carry. In some streams the quantity of the material carried is so great, and the color of the soil is so marked, as to give the water a very characteristic appearance. The rivers that flow from the glaciers of Iceland, and from the slopes of the Andes, are colored milky-white by the soil they carry. In boggy, peaty countries like Ireland the rivers are a deep brown, and in regions where there is an unusual amount of vegetable matter the water may even seem black, as in the Rio Negro in South America. In the United States many streams are almost red from the quantity of red clay that they carry suspended in the water. The natural blue color of pure water is observed only in very clear and deep waters, like those of the Bay of Naples and the Pacific Ocean.

The impurities that give color to rivers are not dissolved matter, but small particles carried along by the current. Material in solution does not usually change the appearance of the water. Sea water and spring waters are almost always exceedingly clear and sparkling, and they always contain mineral matter in solution.

The purest form of natural water is that which falls to the earth as rain. The amount of impurities that can be taken up from the air is never very great, and, after rain has been falling for some time, the most of the impurities of the air have been washed out, so that the water that falls after the first few hours is almost pure. Spring water sometimes has very little mineral dissolved in it, but many springs are charged with considerable quantities of minerals of different kinds. Probably no spring yields water as pure as that found in Lake Loka in Sweden. This lake lies in a basin of hard granite rock on which water has but little effect, and its water contains only one-twentieth of a grain of solid matter to the gallon.

Sea water contains more matter in solution than any other natural form of water. If you think awhile, you will have no difficulty in understanding why this is true. Every stream that flows into the ocean brings a small amount of dissolved mineral water with it. When sea water evaporates the mineral matter, which, as you know, is composed mostly of salt, is left behind. The vapor formed is con-

verted into rain, much of which falls on land and flows back into the sea, bringing more matter in solution with it. In this way, mineral matter in solution is constantly added to the sea, and its water is steadily growing more and more salt.

In speaking of sea water we include the water of lakes that have no outlets, such as the great Salt Lake, in Utah, and the Dead Sea, in Palestine. The water in these contains a much larger proportion of salt than ordinary sea water does, for they have no outlet, and salt is accumulating just as it is in the sea, while, in addition, the water in them is gradually evaporating and the salt is thus concentrated. In the Dead Sea this concentration has gone so far that in a gallon of water there are almost three pounds of mineral matter.

Since water for drinking and domestic purposes should be as nearly pure as possible, the best of all natural waters for these purposes is rain water. However, as this cannot always be had in abundance, and it is difficult to store it and to keep it fresh when stored, the waters of springs, wells, and streams are made use of. In the country, and in small towns, springs and wells generally furnish the water supply; but in cities the great bulk of the water is usually obtained from streams. This is usually purified by some process of filtration, in which it is made to pass through charcoal or some other substance, especially adapted to taking up the impurities.

One of the most common kinds of impurity found in water used in the household is that which produces what is known as "hard water." By "hard water" is meant water that curdles soap and that feels rough to the skin when used for bathing. This quality is due to the presence of lime in the water, and it is frequently noticeable in water of springs and wells. Ordinarily, it cannot be seen, but when hard water is boiled it becomes somewhat turbid or milky, and sediment is deposited from it. When there is much lime present, a coating is formed on the surface of the water as it flows from springs, and articles placed in it will become covered with a sort of crust of lime.

Owing to the effect upon soap, hard water is not well adapted for household use, and it is very desirable to remove the lime if possible. Sometimes this can be done by boiling, in which case the hard ness is said to be "temporary"; at other times boiling does not have this effect, and the hardness is said to be "permanent." "Temporary" hardness is due to the presence of carbonate of lime, which is dissolved by water that contains carbonic acid gas. When the carbonic acid gas is driven out by boiling the water, the carbonate of lime will no longer remain dissolved, but settles to the bottom. "Permanent" hardness is not really permanent. It is due to sulphate of

lime, which dissolves slightly in pure water, and hence is not affected by boiling; but when a little soda is added during the boiling, the sulphate will be deposited just as the carbonate is.

Boiling is a slow and tedious method of removing hardness, however, and a much quicker way is simply to add fresh lime to the hard water. This combines chemically with the carbonic acid gas present, to form more carbonate of lime, and, since carbonate of lime will not dissolve in water in which there is no carbonic acid gas, all the carbonate of lime settles to the bottom, and the water is left soft.

Thus far, all the impurities mentioned as occurring in water have been solids. There is another class of impurities, however, that deserves mention, namely, gases. Water is capable of absorbing some gases in very large quantities and almost all are absorbed by it to a certain extent. Air is almost always found in water, and it is owing to its presence that fish are enabled to live below the surface, for they require oxygen just as truly as land animals do. If water is deprived of the air that it naturally contains, fish drown in it, just as a man drowns in ordinary water. In running water, in which the particles are continually changing their position, and all parts are frequently brought into contact with the air, the percentage of air dissolved is larger than in stagnant water, in which no such disturbance is going on.

Another gas that is frequently found in water is carbonic acid gas, which has been mentioned as being present in "hard water." It is very abundant in geysers, in which it plays an important part in causing the spouting that occurs in them at intervals. By the use of pressure, water can be made to take up large quantities of this gas, which escapes in bubbles when the pressure is removed. What is generally known as *soda water* is nothing but water that has been charged with large quantities of carbonic acid gas.

It would not be proper to close our study of water without a word about the impurity of water which causes more trouble and does more harm than any other — namely, disease germs. These are very small plants and animals — so small, indeed, that they can be seen only by the aid of the microscope, and their presence in water cannot always be detected except by the most careful examination. They are generally far more abundant in streams and wells than in springs, and are likely to be present in water containing much decaying vegetation. Whenever the presence of diseased germs in water is suspected, it should be filtered and boiled, to kill them; for when taken into the body in the water we drink, they may produce illness and even death. Such diseases as typhoid fever are frequently contracted in this way.

Snow, What Depth of, Is Equivalent to an Inch of Rain.—Newly-fallen snow having a depth of about 11⅓ in. is equivalent to 1 in. of rain. A cubic foot of newly-fallen snow weighs 5½ lb., and a cubic foot of fresh or rain water weighs 62½ lb., or 1,000 oz. An inch of rain means a gallon of water spread over every two square feet or about a hundred tons to every acre. The density of snow naturally varies a good deal according to the speed with which it falls. Temperature, also, has much to do with its bulk. In cold, crisp weather, when the thermometer registers several degrees of frost, snow comes down light and dry; but in moist, cold weather, when the temperature is only just below thirty-two degrees, the snow falls in large, partially thawed flakes, and occupies much less space where it falls than that which reaches the earth during the prevalence of a greater degree of cold.

Hail and Rain.—Hail is the name given to the small masses of ice which fall in showers, and which are called hailstones. When a hailstone is examined it is found usually to consist of a central nucleus of compact snow, surrounded by successive layers of ice and snow. Hail falls chiefly in spring and summer, and often accompanies a thunderstorm. Hailstones are formed by the gradual rise and fall, through different degrees of temperature (by the action of windstorms), and they then take on a covering of ice or frozen snow, according as they are carried through a region of rain or snow.

With regard to rain, it may be said, in popular language, that under the influence of solar heat, water is constantly rising into the air by evaporation from the surface of the sea, lakes, rivers, and the moist surface of the ground. Of the vapors thus formed the greater part is returned to the earth as rain. The moisture, originally invisible, first makes its appearance as cloud, mist, or fog; and under certain atmospheric conditions the condensation proceeds still further until the moisture falls to the earth as rain. Simply and briefly, then, rain is caused by the cooling of the air charged with moisture.

ICE-CUTTING AND ARTIFICIAL ICE-MAKING

Every important ice-harvesting company has permanent houses situated on the banks of the bodies of water from which the ice is to be cut. In former years ice-cutting was done entirely by human labor, but to-day, it is accomplished by machinery.

If the water of the lake or river from which the ice is to be taken has frozen by midwinter to a thickness of eight or ten inches, the work of the cutting will soon begin. For the overseeing of the

work only the most experienced ice men are engaged, as the success of the harvesting depends largely on their judgment as to the best time for the cutting. Frequently, a layer of snow congeals on the surface of the ice, and the product becomes what is known as snow-ice. If there is a deep covering of slush on the ice, men, with horses and scrapers, are employed to remove it. After this is accomplished the "marking-off" takes place. This begins where the ice is thickest and best. Simultaneously, the cutting of a channel to the entrance of the ice-houses is under way. The marking-machine is operated much as is a mowing-machine; the operator, from the seat of the machine, guides his horses with one hand, and with the other manages the adjustable saw, that makes in the ice a sharp indentation several inches deep. Following the machine come several groovers who sink heavy steel bars, with pointed ends, through the ice almost to the water beneath. Then there comes the "barring-off" which divides the sheet of ice into pieces about twenty yards in length and ten yards in width. Men, with long hooks, guide these great ice blocks into the channel, where they are termed floats; another gang of men pulls the floats along the channel to the ice-house entrance. Powerful engines in the ice-house are causing the revolution of a great endless chain. As a float appears in the slip, men divide it into blocks about three feet square, each of which fitting into one of the links of the chain is moved up the incline. In this process, the blocks are delayed for a scarcely perceptible moment by a machine, with a set of steel teeth, which hangs stationary above the chain and which tears off the superfluous rough ice or any snow which may still be adhering to the ice blocks. This scraper takes the place of numerous men, who would otherwise have to shave off the rough ice, after this snow scraping. This scraper above the chain is reset for ice of various thickness and quality.

The ice-house is divided into several compartments, which are also called houses. The walls are interlined with hay and tan, and the blocks of ice are packed in tiers until the houses are three-fourths full.

Artificial Ice-making

The consideration of the subject of artificial ice-making may be, for convenience, subdivided under two headings — methods of generation, and methods of application. The systems of generation that are commercially successful are those of absorption and compression. In the first, the principle involved is the absorption of ammonia, or anhydrous ammonia, by water. The material supplied to the circulating system of the apparatus is aqua ammonia.

The complete cycle of operations involves four processes, which are, in order of succession, the generation of gas, the condensation of gas, the expansion of gas, and the absorption of gas. These four processes are constantly repeated, so that the complete process becomes continuous. At the start, ammonia is pumped from the iron drums in which it is delivered into the generator. The generation involves, through the application of heat to the generator, the driving off of ammonia gas, bringing up the pressure from 120 to 160 pounds to the square inch. The ammonia driven off is in a gaseous state. At this pressure, by cooling, it may be reduced to a liquid. This is done in the condensation process. For this purpose, a condenser is used in which the ammonia is conducted through pipes, which are brought in contact with cold water, either by having the water trickle over them or by being immersed in a tank filled with water. Circulation of water is necessary for continuous operation. The ammonia gas gives up heat to the water and is, in consequence, condensed to a liquid. In the next, the expansion process, the refrigeration is produced. The ammonia gas is allowed to pass through a valve which is regulated into a net-work of pipes in the refrigeration chamber. A low pressure is maintained in the expansion pipes. The liquid ammonia, at a high pressure, in entering this system with low pressure, changes from a liquid to a gas. This gas is reduced in temperature by an amount depending upon the initial temperature, the pressure of the liquid ammonia, and the pressure in the refrigerating coils. The cool gas will, accordingly, absorb heat from the pipes and thus produce refrigeration. The low pressure in the refrigerating coils is maintained by the absorber, which contains what is called weak liquid, or water from the generator which has been deprived of the greater part of the ammonia gas. This liquid is accordingly in a condition to absorb ammonia gas again. The absorption process consists in the absorption of the ammonia gas generated in the refrigerating coils by the weak liquid in the absorber. When this liquid in the absorber is charged to the desired degree with ammonia gas, it is pumped to the generator, and is ready to pass through the same series of operations again. The only mechanically operated feature of the absorption system is the pumping.

There is, by the great mechanical operation which constitutes the base of the ammonia-compression system, decided contrast to the methods employed by the absorption system. The compression system occupies a preëminent position in the artificial production of ice. The process consists of a complete cycle involving compression, condensation, and expansion. These three steps are made continuous. The first ammonia-compression ice-machine used in the United States

was erected in 1880. It proved practical, and, with various improvements, is largely used to-day.

The Lindo machine which is also used has a compressor of the double-acting type, and is so constructed that either end of the cylinder can be attached separately or combined to any part of the plant, whereby each works independently of the other, in reality making two single-acting cylinders. The ammonia gas is drawn through the suction valve situated at the upper part of the cylinder head, and is compressed and forced out through the discharge valves situated at the lowest point of the cylinder. The compressed gas then passes into the condenser, having first passed through the oil-trap where any lubricating oil from the compressor is deposited. Between the compressor and the oil-trap is a check-valve, the duty of which is to prevent loss of gas in case of accident to the compressor. The warm compressed gas enters at the top pipe, and passes downward through the successive pipes of the condenser, and by the pressure produced by the compressor and through the cooling influence of the cold water running over the pipes of the condenser, becomes liquified. The liquid ammonia is then discharged into the liquid receiver, generally situated in the engine room, where it is stored for future use.

From the receiver, the liquid ammonia passes to the cellars, storage rooms, chill rooms, and ice-making tank. There it expands to its original gaseous form, and it is this expansion of the liquid ammonia that does the actual work of refrigeration. The expanded gaseous ammonia is then drawn back into the compressor, and sent again on the same round of operation.

In some cases, and for particular purposes, the brine system is used instead of direct expansion. Ammonia, instead of evaporating in the cooling rooms, evaporates in several sets, or nests, of coils placed in a large well-insulated iron or wooden tank, which is filled with a strong solution of salt that can be cooled to the desired temperature. Waters affected by either of the treatments are always distilled and freed from organic matter. It is necessary to run ice-making plants day and night that the drawing off of cakes from cans in the tank may be done with regularity. Machine-made ice supplants the natural product, to a large extent, wherever it is introduced. The cost of cutting, handling, and transporting natural ice, in cities as far north as New York, Philadelphia, and Chicago, permits manufactured ice to be sold there in direct competition, and with gratifying profits. In the Southern States, the manufactured ice is most profitable.

In the latter part of the 18th Century Lavoisier discovered the law of indestructibility of matter or the law of conservation of mass.

Despite its formidable name it simply sets forth that matter may be changed but cannot be destroyed. That when a candle burns or when coal or wood is consumed, not a grain of the candle, the coal, or the wood is destroyed but is changed into some other form of matter.

The law of the conservation of energy is the embodiment of discoveries which prove that no energy can be lost. The ordinary forms of energy are heat, light, electricity, and motion. All of the different forms of energy are convertible into one another without loss of any degree or kind.

The law of definite proportions is the result of a great number of experiments of which an example is here given. If equal parts of iron and sulphur are mixed and heat is applied, it is seen that some of the sulphur is left over in a free state after the action of combination is over. If twice as much iron as sulphur is used, some of the iron is left over. But if seven parts of iron by weight are mixed with four parts of sulphur by weight neither iron nor sulphur is left over. Careful deductions from such experiments have formed the law of definite proportions, that chemical union always takes place between fixed, definite quantities of substances.

The law of multiple proportions was deduced by Dalton from an observation of the fact that iron forms three different compounds with sulphur; that chlorine, potassium, and oxygen combine in four different ways; and that nitrogen and oxygen form five different products. He was able to deduce the law, that when two elements unite with one another in different proportions to form different compounds they do so in masses that bear a simple ratio to one another. For example when carbon and hydrogen unite to form olefiant gas the proportion is six parts of carbon to one part of hydrogen; when they unite to form marsh-gas, the proportion is 3 to 1 or 6 to 2. The quantity of hydrogen is just twice as great in one case as in the other.

It has been said that the symbols represent not only the element but a definite quantity of that element. Thus H means not only Hydrogen but one atom of Hydrogen. Cl means not only Chlorine but one atom of it. These symbols are sometimes the first letter of the name of the element, as H, O, C, and N for Hydrogen, Oxygen, Carbon, and Nitrogen. Sometimes where several elements begin with the same letter, another letter is taken and added to the first, as Cl for Chlorine, Tl for Thallium, and Pt for Platinum. Sometimes the Latin name for the element is used to guard against confusion, as Au for Gold from the Latin Aurum; Ag for Silver from the Latin Argentum; or Pb for Lead from Plumbum.

Formulas are combinations of these symbols which are written side by side to show the chemical formation of compounds and to

express one molecule of that compound. For instance one atom of Hydrogen unites with one of Chlorine to form one molecule of Hydrochloric Acid. This is written HCl. Two atoms of Hydrogen, one of Sulphur, and four of Oxygen unite to form one molecule of Sulphuric Acid, which is expressed by H_2SO_4. The small figure below the line goes with the letter before it just as the exponent does in algebra. If two molecules of Sulphuric Acid are to be written, a large numeral is placed before the formula as $2H_2SO_4$, and it multiplies all of the symbols that follow it, just as the numerical coefficient does in algebra. The use of the chemical symbols and formulas helps to make clear the chemical reactions that take place. For instance when Hydrochloric or Chlorhydric Acid (HCl) is made by pouring Sulphuric Acid (H_2SO_4) upon Sodium Chloride or Common Salt (Na Cl), the reaction that occurs is expressed thus:

$$2\ Na\ Cl+H_2SO=Na_2\ SO_4+{}_2HCl.$$

This is an equation, for it will be observed that there are the same number of atoms of elements on one side of the sign of equality as upon the other. 2 of Sodium, 2 of Chlorine, 2 of Hydrogen, 1 of Sulphur, and 4 of Oxygen. But there is more to be learned from this equation. The Sodium (Na) has left the Chlorine (Cl). The Hydrogen of the Sulphuric Acid (H_2SO_4) has united with the Chlorine to form Chlorhydric Acid, and the Sodium (Na) has united with the Sulphate radical (SO_4) of the Sulphuric Acid to form Sodium Sulphate (Na_2SO_4).

Acids, in chemistry, are substances which generally have a sour taste, turn blue litmus red and are composed of Hydrogen chemically united with some negative element or radical. They are used extensively in arts and manufactures. Sulphuric Acid is probably one of the most useful substances in the world.

Bases are substances which have a caustic taste, turn red litmus blue, and have the power of neutralizing acids. When dissolved in water (H_2O), they replace one atom of the Hydrogen and the remaining atom of Hydrogen and that of Oxygen form the Hydroxyl radical (OH) which is found in the formulas of solutions of this class of bodies. The commonest of the bases are known as alkalies. Such are Ammonium Hydrate or Common Ammonia (NH_4OH), Sodium Hydrate (NaOH), Potassium Hydrate (KOH). Salts are compounds produced by neutralizing an acid by a base. If Sodium Hydrate (Na OH) be mixed carefully with Chlorhydric Acid (HCl) in such proportions that the mixture resulting will have no effect upon either red or blue litmus, and if the solution be evaporated to dryness,

a white powder will result which is Sodium Chloride or Common Salt (Na Cl). The reaction may be represented by the equation:

$$Na\ OH + H\ Cl = Na\ Cl + H_2O.$$

In a similar way acids and bases may be made to neutralize one another and the several salts be formed. All salts do not possess a salt taste. The name was so given to the class because Common Salt was one of the first to be discovered.

NAMES OF ACIDS.—The names of many acids end in -ic, as Chloric, Sulphuric, Nitric, Carbonic, etc. Others end in -ous, as Chlorous, Sulphurous, Nitrous, etc. The -ic termination means that there is a larger amount of Oxygen in that acid than in the -ous compound. To illustrate. When the acids whose composition is expressed by the formulas $H\ Cl\ O_3$ and $H\ Cl\ O_2$ were discovered the first was seen to have three atoms of Oxygen and the second only two. Therefore the first was called Chloric and the second Chlorous. Later one was discovered whose formula is $H\ Cl\ O_4$ and another one HClO. The terms -ic and -ous were already in use. So the $HClO_4$ was called Perchloric Acid and the HClO was called Hypochlorous Acid. The prefix per- signifies more Oxygen than an -ic acid; and the prefix hypo- less oxygen than an -ous acid.

NAMES OF SALTS.—Salts are named partly from the base and partly from the acid from which they are produced by neutralization. An -ic acid gives an -ate salt. Chloric acid gives a Chlorate; Sulphuric acid gives a Sulphate; Carbonic acid, a Carbonate; Nitric acid, a Nitrate. An -ous acid gives an -ite salt. Chlorous acid gives a Chlorite; Hypochlorous acid, a Hypochlorite; Sulphurous acid, a Sulphite; Hyposulphurous acid, a hyposulphite.

An -ide compound is formed by the direct union of two elements. When Zinc and Chlorine unite they form Zinc Chloride; Zinc and Sulphur, a Sulphide. These terminations may be well exemplified by this statement: A Sulphate results from union with Sulphuric Acid; a Sulphite from Sulphurous Acid; and a Sulphide from a direct union of Sulphur. When Oxygen unites with substances directly the great class of bodies known as oxides results.

COMPOUNDS OF NITROGEN

Nitrogen has been described under the heading of Air; and some of the properties of one of its most important compounds—Ammonia—have been noted. Ammonia is a gas. Its formula is NH_3. When dissolved in water it forms aqua ammonia or hartshorn and its formula is then NH_3+H_2O or NH_4OH. NH_3 and NH_4 must be dis-

tinguished. NH_3 is Ammonia gas; NH_4 has no separate existence; it is Ammonium and is regarded as a radical. A radical may be defined as a group of elements that, as a group, cannot exist alone but only in combination with other element or elements. In this way SO_4 is known as the sulphate radical as it exists in all sulphates; and NO_3 is the nitrate radical as it is found in all nitrates.

The NH_4 radical, or Ammonium, combines with other elements and forms bases and salts of Ammonium; as with the Hydroxyl radical OH to form NH_4OH, or Ammonium Hydrate; with Chlorine to form NH_4Cl, or Ammonium Chloride or Sal Ammoniac, a white salt that is much used in electric batteries.

Probably the most important compound of Nitrogen is Nitric Acid (HNO_3). It may be prepared by treating any nitrate with Sulphuric Acid. Such as Sodium Nitrate ($Na\ NO_3$), when the reaction is $2\ Na\ NO_3+H_2SO_4=Na_2SO_4+2HNO_3$. One of the peculiar properties of Nitric Acid is that it turns animal substances yellow. A feather dipped in it, or a drop upon the finger, produces a yellow stain. It has a corrosive action upon metals and will readily dissolve all except gold and platinum. When Nitric Acid is mixed with Hydrochloric Acid, the mixture is known as Aqua Regia or the King of Liquids as it will dissolve gold readily. As Nitric Acid will dissolve the other metals and not act upon gold, it is often used as a test for gold. If a drop placed upon a yellow metal leaves a stain or mark, it is safe to say that the metal is not gold.

Nitric acid is used largely in the preparation of gun-cotton, nitro-glycerin and xyloidin. Gun-cotton is made by treating carded cotton with a mixture of concentrated nitric and sulphuric acids. It was first used for military purposes in the Austrian army. It is used largely for torpedoes and in military and naval operations by all countries. Nitro-glycerin was discovered in 1847. It is prepared by pouring glycerin into a mixture of concentrated nitric and sulphuric acids. It is an oily, clear, colorless fluid with a sweetish taste. It burns without explosion, but explodes terrifically when struck or jarred violently. Solid gunpowder is often soaked in it for blasting. Nobel, a Swede, mixed it with ashes and also with infusorial earth and made dynamite, in which form it is regarded as the safest of explosives. A mixture of gun-cotton, nitro-glycerin and vaseline forms "smokeless powder" or cordite. It is used in cartridges in the form of small sections of vermicelli. The British soldiers in the Boer War discovered that eating this was followed by a sort of exhilaration or intoxication. This is due to the stimulating properties of nitro-glycerin which is used in small doses in medicine, to stimulate the heart's action in cases of collapse.

there are five oxides of nitrogen, viz:

Nitrous Oxide, or Laughing Gas	N_2O
Nitric Oxide	NO or N_2O_2
Nitrogen Trioxide	N_2O_3
Nitrogen Peroxide	NO_2 or N_2O_4
Nitric Anhydride	N_2O_5

This series is a splendid illustration of the Law of Multiple Proportions. The first of the series, Nitrous Oxide or Laughing Gas, is of the greatest use in dentistry as an anæsthetic for operations that require only a short period of unconsciousness. It is colorless and transparent and has a slightly sweetish taste. As it gives rise to hysterical laughter it takes the common name. It is condensed into a liquid state and stored in strong cylinders for transportation. As soon as the pressure is released it escapes in the form of gas. N_2O_5 is called Nitric Anhydride, because if it is mixed with water Nitric Acid results thus:

$$N_2O_5+H_2O=H_2N_2O_6 \text{ or } 2HNO_3.$$

Anhydride means "without water" and is a term applied to all substances which, when brought into contact with water, form acids.

Carbon.— This is the all-important element of the animal and vegetable kingdoms. Its compounds are exceedingly numerous and varied. It occurs in a great many forms as an element. Some of these are crystalline, as the diamond and graphite or plumbago. Others are amorphous, that is, not crystalline, as charcoal, coke, lamp-black, bone black or animal charcoal, hard and soft coal. The diamond is the purest form of carbon. Under intense heat the diamond will swell up into a shapeless black mass and then burn, leaving only a trace of ash. Diamonds have been made by plunging charcoal into molten iron in an electric furnace. They are usually white, but from foreign substances sometimes assume various colors. They are cut usually into either brilliants or rose diamonds. They are found chiefly in Brazil, South Africa, and India. The largest diamond, "the Cape Diamond," was found in the mines at Kimberley, South Africa, in 1880. It weighed in the rough 475 carats; when cut, 300 carats. The famous Koh-i-noor originally weighed 800 carats, but by the awkward cutting it was reduced to 279 carats. It was then recut and now weighs $106\frac{1}{10}$ carats.

The Largest Diamonds in the World

Name.	Carats Cut.
Braganza	367
Star of the South	254

Name.	Carats Cut.
Orloff	194
Florentine	139½
Pitt	136¾
Koh-i-noor	106 1-10
Shah	86
Pigott	82½
Nassac	78
Blue	67⅓
Sancy	53
Dudley	44½
Pacha of Egypt	40

The diamond and other gems are weighed by the carat, which is about 3.2 grains Troy.

Graphite.—Also called, but incorrectly, plumbago and black lead, is an allotropic form of carbon, and in composition identical with charcoal and with diamonds. As a mineral it occurs both massed and disseminated in rock, generally in granite, gneiss, mica schist, and crystallized limestone. It is used largely in the manufacture of lead pencils, and in electrotyping. In its crystalline form it is produced largely at Ticonderoga, N. Y., as well as in Clay Co., Ala., and in Chester Co., Pa. The amorphous graphite is mined in R. I. and in Mich. It is also found in Cumberland, England, in Ceylon, Siberia, and in parts of Austria, Germany, and France. An artificial graphite, produced from carbon, is manufactured by the Carborundum Co., at Niagara Falls, N. Y. The quantity of amorphous graphite produced in this country in 1899 was over 2,300 short tons, while of refined crystalline graphite the U. S. produced in the same year nearly 3,000,000 pounds weight. Another concern at Niagara Falls, N. Y., produced in 1899 over 400,000 pounds of graphitized carbons for use in the shape of anodes and electrodes in alkali manufacture and for self-lubricating motor brushes. Graphite is now also produced powdered and in flakes.

Charcoal is made by charring, or burning with slight access of air, organic substances which contain carbon, hydrogen, and oxygen. Charcoal has the power of absorbing gases and of purifying the air. It is used as a filter for pumping water. This property depends upon its porosity. Bone-black is made by charring bones. It has the additional property of decolorizing vegetable coloring matter and is much used in the preparation of white sugar.

COAL

One of the most important of minerals, is of vegetable origin, and in large use as fuel in furnaces, in stoves, and in grates for the heating of rooms, etc. Its consumption in these manufacturing days is enormous, the world's output of coal for the year 1903 being estimated at close upon 650 million tons. In this country, the supply is adequate for an indefinite period, though in Britain, at the present rate of consumption, the coal fields of the United Kingdom will, it is estimated, become exhausted in 200 years, while the bulk of the readily available supply is likely to give out in 50 years. The coal consumption of the United States equals that of Great Britain, viz., about 220 million tons per annum. The other chief coal producing countries, besides the United Kingdom and the United States, are Germany, France, and Belgium. Austria-Hungary and Russia come next in the order of national coal consumption. The chief varieties of coal are anthracite (hard), bituminous (soft), and lignite or brown coal. British coal is nearly all soft; while in this country we possess both, and are especially rich in the vast anthracite coal regions of Eastern Pennsylvania. The origin of coal, it is now well determined, is vegetable matter, which has undergone great changes from the length of time it has been stored within the earth, and the various influences to which it has been subjected. The mass of European coal belongs to the deposits of what is known as the Carboniferous era; the enormous coal fields of India and China belong, on the other hand, to the later, Permian era, and still other fields to the Miocene age.

Coal, World's Yearly Output of.—The United States now takes the first place, long held by Great Britain, among coal-producing countries. In 1900 the production of bituminous coal in the U. S. amounted to 220,592,239 short tons, valued at $224,502,483 at the pit's mouth, while the year's yield of anthracite coal in the U. S. (chiefly raised in Pennsylvania) was 54,225,540 short tons, valued at the mine at $97,-229,032 (or $1.79 per ton). The total of the great product for the year (1900) was in short tons 274,872,779, valued at $321,792,265 (or per average ton, of hard and soft coal, $1.17). Appended on the following page is the coal yield for the year 1898 in the principal coal-producing countries of the world.

Ton Price.—The average value per ton of coal at the mine is highest in France (which has to add to her store annually by importation), where it is $2.25 per ton at the pit's mouth, and lowest in the U. S., where it is only $1.10 per ton. In the other three chief European coal-producing countries, the mine price per ton is as fol-

Coal Yield for the Year 1898

Country	Tons of Coal Mined, 1898
Australasia	6,316,000
Austro-Hungary	12,186,000
Belgium	21,918,000
Canada	4,173,000
Cape Colony	192,000
France	32,331,000
Germany	101,622,000
India	4,605,000
Japan (1897)	5,188,000
Natal	388,000
Russia	12,185,000
Spain	2,434,000
Sweden	236,000
Transvaal (1897)	1,600,000
United Kingdom (1900)	230,094,781
United States (1900)	274,872,779

lows: in Belgium it is $2.20; in Germany it is $1.85; and in the United Kingdom it is $1.60. Owing to the coal famine in some countries of the European continent, the average export price in England has advanced of late from $2.50 to $3.75 per ton. In this country, the local price per ton at the mine varies with the region and yield of the coal production. The range in price is from 70c. to $2.70 per ton. The states which yield most abundantly of bituminous coal are Pennsylvania (87 million tons annually), Illinois (25 million), Ohio and West Virginia, which each yield 21 million tons yearly. Next to these in bulk of production are Alabama, Colorado, Kentucky, Indiana, Tennessee, Wyoming, Iowa, Kansas, and Maryland.

At high temperatures, carbon has the power of combining readily with oxygen. This is known as reducing. For this reason it is much used in extracting metals from their ores. The compounds of carbon with hydrogen are called hydrocarbons. There are two oxides of carbon. Carbon dioxide, or carbonic acid gas (CO_2); and carbon monoxide (CO).

Carbonic Acid or Carbonic Anhydride, formerly called *fixed air*, is a gaseous compound of carbon and oxygen. It is procured by the processes of combustion and respiration, and hence is always present in the air, though in minute quantity. Plants live upon it and absorb it into their tissues, there abstract and assimilate its carbon, and return its oxygen to the atmosphere in a pure condition. It is also present in spring water and often in quantities so that it sparkles and effervesces; it is also produced during the processes of putrefaction, fermentation, and slow decay of animal and vegetable substances

in presence of air. It is largely employed by the manufacturers of aërated bread and aërated waters. Under a pressure of about 600 pounds it liquefies, and when allowed to escape through a small jet it rapidly evaporates and causes intense cold, so much so as to become frozen. It does not support burning. The gas derived from it, carbon dioxide, is invisible, and is heavier than air by one-half, and has a pungent odor and slightly acid taste. In a pure state the gas cannot be respired, as it supports neither respiration nor combustion. When the portion in the atmosphere is increased to a considerable extent, as happens sometimes, it endangers life. The familiar "rising" of bread is brought about by carbonic acid gas escaping through and permeating the dough, making it light and porous. In this form it is known as yeast or as baking powder. We see its uses also in the chemical fire engine.

Carbon monoxide is more poisonous than the dioxide. It burns with a pale, blue light. It is that flickering blue flame that is seen when hard coal burns. The escape of this gas from the stove is often the cause of asphyxiation.

ILLUMINATING GAS

If YOU hold a cool glass tumbler over a burning gas jet for a moment, you will see a little film of moisture form on the inside of it and remain until the tumbler becomes warm, when it will disappear. Can you tell what causes this film? And does it give you any hint of the composition of the gas that is being burned? Think a moment, and you will remember that water is composed of oxygen and hydrogen, and that when hydrogen is burned in the air, water is formed. It is equally true, that whenever water is formed by burning anything, hydrogen is present in it. So, you see, the gas used for lighting purposes must contain hydrogen.

Let us now see whether we can find out something more about the composition of gas. Take a piece of glass and wet it with a little fresh lime water and hold it over the gas flame. Wait for a few moments and see whether any change takes place in the water. A change does occur; the water turns somewhat milky. This, you remember, shows the presence of carbonic acid gas, and the formation of carbonic acid gas, when burning is going on, shows that the element *carbon* is present.

From these two simple experiments, we learn that illuminating gas contains hydrogen and carbon. An examination of any kind of illuminating gas will show that these two substances are always

present. Sometimes there are comparatively small quantities of other substances found in the gas, but its value for lighting purposes depends on these two.

Something has already been said about hydrogen, in connection with water; but nothing has been said about carbon, about which you must now learn something, if you want to understand how illuminating gas is made.

Carbon is one of the elements, and a very important one it is, for it enters largely into the composition of every living thing in the world, as well as into some without life. It forms more compounds than any other element, and occurs in more different forms. To obtain tolerably pure carbon, all that is necessary is to heat a piece of wood, in a closed vessel, until it is converted to charcoal. This black substance is made up almost entirely of carbon. Its properties are of considerable interest, but the only one that we now wish to note, is the readiness with which it burns when heated in the air or in oxygen.

Charcoal has much the same composition as hard coal, and both are formed in much the same way. Thousands of years ago many large forests of trees, somewhat different from those we now see, were covered over with soil and rocks, during changes that occurred in the earth's surface, and the heat inside the earth slowly charred the wood, until almost nothing was left but the carbon.

Soft coal was formed in the same way, but the process was not carried so far. Along with the carbon in soft coal, we find a considerable quantity of other substances, of which hydrogen forms the greater part. It is this fact that makes soft coal useful in the manufacture of illuminating gas.

When soft coal is heated in a closed vessel, a gas is driven off that will burn. This may be shown by taking an ordinary clay tobacco pipe, putting a small piece of coal in the bowl, closing the opening with wet clay, and putting the bowl of the pipe in the fire. After it has become quite hot, a gas will be found issuing from the stem of the pipe that will take fire and burn.

This is in a small way just what is done in the manufacture of coal gas. Soft coal is heated in large tubes of fire clay called *retorts*, and the gas that is driven off is purified, and is then conducted through pipes to our houses. The part of the coal that cannot be converted into a gas by heat is left behind in the retort. It consists largely of carbon and is known as *coke*.

While the gas that comes directly from coal will burn, if brought into contact with flame, it is far from being a desirable gas to burn in our houses. It has in it a number of substances that must be re-

moved to fit it for general use, so that the purification of the gas is quite as important as its extraction from coal.

From the retorts the gas passes into a horizontal pipe containing water, which cools it and causes most of the tar and water-vapor that are driven off with it to become liquid and settle in the water. From here the gas goes on through a series of curved pipes, which are kept cool by the air, and in which some more tar settles. This series of pipes is known as the *atmospheric condenser*, and from it the gas passes on into a series of vessels containing coke, over which a fine spray of water is constantly being blown. These are the *scrubbers*, and they serve to remove the last traces of tar and some of the sulphur compounds, that are always present. The removal of the latter is very important, for when sulphur is burned, the gases given off are not only extremely unpleasant to breathe, but they are most injurious to both health and property.

From the scrubbers the gas passes on to the *purifiers* — vessels containing trays filled with lime and oxide of iron. Here the remainder of the sulphur compounds are absorbed, partly by the lime and partly by the iron, and at the same time the lime absorbs a small quantity of carbonic acid gas, which is formed with the other gases. From the purifiers, the gas passes into great iron tanks, in which it is stored until needed.

The gas, as it is stored in the tanks or gas-holders, consists mainly of hydrogen, a number of compounds of hydrogen and carbon, and a small amount of a compound of carbon and oxygen containing less oxygen than carbonic acid gas, and known as *carbon monoxide*. Of these, the hydrogen and carbon monoxide burn with a very pale flame, that gives very little light, but much heat. The light-giving quality of the gas is due to the compounds of carbon and hydrogen. When these burn, the particles of carbon are heated white hot and glow very brightly, making the flame luminous.

There are, of course, in the purified gas some traces of the impurities, that were for the most part removed. These are compounds containing sulphur and ammonia. The quantities of these substances left in the gas after the process of purification are so small that they do no harm; but the quantities absorbed in the process of purification are quite large, and considerable use has been made of them. The water used for washing the gas is heavily charged with ammonia and is, in fact, the chief source of the ammonia sold by druggists.

In addition to coal gas made in the way just described, there is another form of illuminating gas, in the manufacture of which coal is indirectly employed. This gas, known as *water gas*, because it is formed by the decomposition of water, is produced by passing steam

over red hot carbon, in the form of hard coal or coke. When this is done, the hydrogen in the steam is set free and the oxygen combines chemically with the carbon, to form the carbon monoxide, that was mentioned as being present, in small proportions, in ordinary coal gas. This carbon monoxide is poisonous, if much of it is breathed, and as it has no odor it is difficult to detect when escaping. A number of deaths have resulted from water gas for this reason, and in some states the laws forbid its use for lighting purposes.

When water gas is used it must be enriched with some other substances, before it will yield much light. You have already learned that neither hydrogen nor carbon monoxide burns with a bright flame, and you will see that water gas must have something added to it to fit it for lighting purposes. The substance usually added is the vapor of some light, volatile oil, like gasoline. This vapor is composed of compounds of carbon and hydrogen, and when it is mixed with the water gas it forms a gas that yields a very satisfactory light; and that may be produced more cheaply than common coal gas.

There remains one more form of illuminating gas which has been the subject of much discussion in recent years, namely, *acetylene*. This is a compound of carbon and hydrogen, in which there is twelve times as much carbon as hydrogen. It has not been discovered recently, for it was known early in the 19th century, but its possible use for lighting purposes was not considered then.

Attention was directed to it a few years ago by the discovery of a substance called *calcium carbide*. This is a compound of carbon and the metal calcium, formed by heating to a very high temperature a mixture of coal and lime. It has the peculiar property of decomposing, when treated with water. The calcium present combines with the oxygen and half the hydrogen of the water, to form common slacked lime or *calcium hydrate*, while the carbon and the remainder of the hydrogen combine to form acetylene gas.

The gas formed in this way needs no purification before burning; it can be produced in small generators, and the production can be checked at any time. When burned in the proper form of burner it yields the brightest of all gas flames. For these reasons, it is adapted for use in small villages and for lighting single houses. It is also frequently used in magic lanterns, where a strong and steady light is necessary. But the cost of producing acetylene in large quantities is greater than that of coal gas, and it seems extremely unlikely that it will ever be much used for lighting large cities and towns.

Hydrocyanic or Prussic Acid (HCN).— This is a compound of Carbon and Nitrogen with Hydrogen. It is a volatile liquid. Its odor

resembles bitter almonds. It dissolves readily in water. It is found in nature in small quantities in bitter almonds, and in the leaves and kernels of the fruit of the cherry and laurel. It is a deadly poison. Its compounds are known as Cyanides.

When carbon unites directly with metals it forms Carbides.

Avogadro's Hypothesis. — Several phenomena in chemistry are not capable of direct proof, but their explanation is supported by theories and hypotheses which have not been disproved in any particular and are accepted as Laws. One of these is the atomic theory which has already been explained; another is Avogadro's hypothesis, which is stated in these terms: Equal volumes of all gases under the same conditions of pressure and temperature contain the same number of molecules. By this law it is possible to determine the weights of equal volumes of gases; for they will bear the same relation to one another that the weights of the molecules of their substances do. The molecular weight, or the weight of a molecule, of any compound is the sum of the atomic weights of the elements of which it is composed. For example: the weight of a molecule of hydrochloric acid is 36.4 which is made up of 1 and 35.4, the atomic weight of hydrogen and chlorine respectively. The molecular weight of an atom is twice the atomic weight of that element. Thus the molecular weight of hydrogen is 2, of chlorine 70.8.

In chemical combination, of any sort under any conditions, the molecules of either elements or compounds must be broken up into atoms before a reaction is possible. When these atoms are freshly liberated from their molecular state, they are said to be in a nascent state, or in a condition of being just born. In this condition they are much more active than when in the molecular state. A good instance of this is to be found in the case of nitrogen. The atmosphere contains very large quantities of it, but it is very inert, and, although plants need it for their growth, they cannot use it in this way. It will not unite with other substances or enter at all into the growth of the plant. When, however, Ammonia (NH_3) is broken up and the nitrogen set free, the nitrogen in the nascent state is very active and enters freely into the plant economy.

Valence. — Every element has the power of attracting other elements to it. This power is not the same for all elements. This combining power is called the valence of an element. When hydrochloric acid (HCl) is broken up into its elements of hydrogen and chlorine it is found that there is just as much hydrogen by volume as there is chlorine. This leads to the conclusion that each atom of hydrogen has the power of attracting one atom of chlorine, and, also that each atom of chlorine has the power of attracting one atom

of hydrogen. Therefore hydrogen and chlorine are each said to be univalent. Water (H_2O) is seen to contain twice as much hydrogen as oxygen. Therefore an atom of oxygen is said to have the power of attracting two atoms of hydrogen. Therefore oxygen is said to be a bivalent element. Similarly Calcium Chloride ($Ca\ Cl_2$) is found to contain twice as much Chlorine as Calcium. Therefore Calcium is said to be a bivalent element. Calcium Oxide (CaO) on analysis contains equal quantities by volume of calcium and oxygen. This proves that one atom of a bivalent element requires two atoms of a univalent element to satisfy its combining power while it will be satisfied with one atom of another bivalent compound. The formula of Ammonia (NH_3) shows that one atom of Nitrogen holds three atoms of Hydrogen. So Nitrogen is said to be a trivalent element. Marsh-gas (CH_4) shows that carbon can hold four atoms of a univalent element, hydrogen, therefore it is said to be a quadrivalent substance. Some rare cases are known where elements can hold five, six and even seven univalent atoms in combination. In chemical union the atoms that are attracted by the atom of high valence, need not be all of the same element. Let us consider the union of the atoms of Nitric Acid (HNO_3). Here we have the union of one atom of hydrogen, a univalent element; one of nitrogen, a trivalent element; and three atoms of oxygen, a bivalent element. It is plain that if one atom of oxygen has a power of attracting two univalent atoms, three atoms of oxygen can hold six univalent atoms. If we consider that a univalent atom has one bond of attraction; a bivalent two; and a trivalent three; and if we represent these bonds by lines, the union will be made clearer by a diagram. $H—O—O—N═O$. Here it may be seen that hydrogen has one bond connecting it with the first atom of oxygen. The first atom of oxygen has two bonds, one connecting it with the hydrogen atom, the other connecting it with the second atom of oxygen. The second atom of oxygen is connected by one bond with the first atom of oxygen, by the other with the atom of nitrogen. The nitrogen atom has three bonds, one connecting it with the second atom of oxygen, and two connecting it with the third atom of oxygen. The third atom of oxygen has two bonds connecting it with the atom of nitrogen. All of the bonds are satisfied according to the valence of each atom, hydrogen one, all of the oxygen, two each; and nitrogen three. It has been said that NO_3 is the nitrate radical; and a radical has been defined as a group of elements having no separate existence but entering into combination as a single element. If we regard it as such the combining power is more easily explained. For then the nitrate radical would be considered as having only one free bond, and it would be con-

sidered a univalent radical; and to this free bond an atom of hydrogen is attracted. Copper nitrate is written $Cu(NO_3)_2$. Copper is bivalent and requires two univalents of the nitrate radical to satisfy it. It may be represented by the diagram: O=N—O—O—Cu—O—O—N=O, where copper has two bonds and all the rest of the other elements of the two equivalents of the nitrate radical are satisfied.

Sometimes one element may have different valences. This is explained by the more or less favorable conditions of chemical action at the time of union. The causes may be temperature, a higher temperature being unfavorable to greater activity; the character of the element with which the union is effected. Lead is either trivalent or quinquivalent; so are phosphorus and nitrogen.

Chlorine Group.—The elements are arranged in groups, each member of which has some marked resemblance to the others of the group. This is in obedience to the Periodic Law, which is known as Mendelief's Law, named after the Russian chemist who discovered it. It was developed by Lothar Meyer. It is summed up as: The properties of an element are periodic functions of its atomic weight. The elements of chemistry are arranged in a table in the order of their atomic weights and so close do all those of close atomic weights resemble one another, that if the atomic weight of an element is known, its properties can be stated from that fact alone with considerable accuracy. The chlorine group comprises chlorine, bromine, fluorine and iodine.

Chlorine.—Cl (At. Wt. 35.4). Chlorine is a greenish-yellow gas, with a disagreeable pungent odor. It is poisonous when inhaled full strength. It is soluble in water and is heavier than air. Its most marked peculiarity is its rapid union with hydrogen. Upon this depends its bleaching power as well as its disinfecting properties. In both cases it is because it unites so readily with the hydrogen of the coloring matter or in the offensive matter and breaks up the compound, forming with the hydrogen a weak solution of hydrochloric acid. It will act only upon vegetable and animal dyes, but not upon mineral and other dyes which contain no hydrogen. It will bleach writing ink, but not printer's ink.

Chlorine unites with the metals to form chlorides. Among the most important chlorides are sodium chloride or common salt (Na Cl) and hydrochloric acid (HCl).

SALT AND SODA

SALT and soda are two of the substances with which we have to do most constantly in our daily lives, and they have many important uses. With the exception of water, which has already been discussed, there are probably no chemical compounds that are more frequently used by all civilized people than salt and soda. They are of interest for this reason, and also because from the study of them, you can obtain knowledge that will enable you to understand more readily many facts concerning other things.

You have already learned, from what was said of air and water, the difference between a mere mixture of substances and a chemical compound. You remember that when substances are only mixed together they do not lose their ordinary properties, and that they may be mixed in any proportions, while in a compound, on the contrary, the substances are always combined in fixed proportions, and the properties of the compound are often very different from those of its separate components. Knowing this, you may not be surprised to learn that the common salt, that you eat with your food, is made of two substances, that are not at all like salt, and are very different from each other. One is a soft, bluish metal, called *sodium*, and the other is a yellowish-green gas called *chlorine*, while fine salt is a mass of colorless crystals. Because it is composed of these two substances, the chemical name for salt is *sodium chloride.*

Sodium and chlorine are both simple *elementary substances* or *elements*. By this we mean that they cannot be separated into substances of different kinds. Oxygen, nitrogen, argon, and hydrogen belong to this class, and an examination of all the different kinds of substances obtainable has led to the discovery of about seventy such elements. All the substances around us are composed of these elements chemically united in different compounds, or simply mixed together. Most of them, however, are mixtures, not of separate elements, but of compounds. The soil under our feet is a mixture of compounds, as is also the impure water found in nature. Indeed, pure compounds very rarely occur naturally. Salt, or sodium chloride, to give it its chemical name, is sometimes found almost pure; but in order to get it perfectly so, we have either to make it in the laboratory out of pure materials, or to separate its natural impurities from it. Fortunately, salt, which contains so little impurity that for practical every-day use it is generally unnecessary to purify it at all, is found in large quantities.

The chief sources of salt are the sea water, in which it is dissolved with some other substances; salt beds, formed by the drying

up of old lakes that have no outlets; salt wells, that yield strong brine; and salt mines, in which it is found in hard, solid, transparent crystals, called *rock salt*. Rock salt is the purest form in which salt is found and, to prepare it for market, it is merely ground or cut into blocks. The greatest deposit of salt in the world is probably that at Wielizka in Poland, where there is a bed 500 miles long, 20 miles wide, and 1,200 feet thick. Here some of the mines are so extensive that it is said some of the miners spend all their lives in them, never coming to the surface of the earth. A tour through these mines reveals many interesting things, among them a large church cut entirely out of salt. The salt supply of the United States is obtained chiefly from the salt wells of Michigan and New York, the Great Salt Lake in Utah, and the rock-salt mines of Louisiana and Kansas.

In the arts and manufactures, the most important uses of salt are in glazing earthenware, in extracting metals from their ores, in preserving meats and hides, in fertilizing arid soil, and also, as we shall presently see, in the manufacture of soda. Of equal importance, perhaps, is its use in food. Most people think it not only lends a pleasant flavor, but is itself an important article of diet. It is certain, that all people who can obtain it use salt in their food, and where it is scarce, it is considered one of the greatest of luxuries.

Soda is of interest to us, not so much on account of its use in our households as because it plays an extremely important part in two industries that contribute greatly to our comfort, viz., the manufacture of glass and soap.

Soda is not found naturally in great abundance, as salt is, but is generally made from other substances. Formerly it was made almost entirely from the ashes of certain plants. One known as the Salsola soda-plant, was formerly cultivated in Spain for the soda contained in it, and the ashes, or Barilla, as they were called, were soaked in water to dissolve out the soda. Now, however, the world's soda supply is produced from common salt by two processes, known from the names of their inventors as the Leblanc and Solvay processes.

In the Leblanc process the first step is to treat the salt, or *sodium chloride*, with sulphuric acid. As a result of this, a compound of sodium, sulphur, and oxygen, called *sodium sulphate*, is formed, together with another acid containing hydrogen and chlorine, and called *hydrochloric acid*. This acid is driven off by boiling, and the *sodium sulphate* is left.

The next step in the process is to convert the sodium sulphate, or "salt cake," into soda or, to give it its chemical name, *sodium carbonate*. This change is brought about by mixing the salt cake with

limestone and coal and heating the mixture. Just what changes go on when this is done is not known, but the chief ones are probably the following: The coal, which consists for the most part of an element called *carbon*, takes the oxygen out of the *sodium sulphate*, and unites with it to form carbonic acid gas, leaving a compound of sodium and sulphur called *sodium sulphide;* this acts on the limestone, which is composed of a metal, *calcium*, in combination with carbon and oxygen, and causes the sulphur in the *sodium sulphide* to combine with the calcium, forming *calcium sulphide*, while the sodium combines with the carbon and oxygen and forms the desired compound, *sodium carbonate.*

After the heating, the resulting mass which contains calcium sulphide, sodium carbonate, and some unburned coal, and is known as "black ash," is broken up and treated with water. This dissolves the sodium carbonate, leaving the rest undissolved, and when part of the water is evaporated crystals containing sodium carbonate and water are formed. By heating these the water may be driven off, and the sodium carbonate left behind as a white powder.

The Solvay, or *ammonia soda*, process consists in forcing carbonic acid gas through strong brine, to which a considerable quantity of ammonia has been added. When this is done crystals are formed in the brine, which are composed of a compound of hydrogen, sodium, carbon, and oxygen, and are called *sodium bicarbonate.* This substance, which is the soda we sometimes use in baking bread, is decomposed by heating into water and *sodium carbonate*, the soda used for washing.

The Leblanc process was formerly used almost altogether for making soda; but in recent years the Solvay process has come into extensive use, and it is said that now more than half the soda of the world is made in this way.

Hydrochloric acid is prepared by treating sodium chloride, common salt ($NaCl$), with sulphuric acid. The acid is given off in the form of gas, and it is then dissolved in water. It is colorless and transparent, with a sharp taste and smell. It is very soluble in water. One quart of water will dissolve 450 quarts of the gas. The yellow color of the acid solution is caused by impurities. A common compound of chlorine is the "Chloride of lime." It is really not the chloride (KCl) but more properly Chlorinated lime, in which form it is used as a bleacher and a disinfectant. A deodorizer is a substance which kills a noxious odor, usually by substituting a more powerful odor which only disguises the trouble. A disinfectant, such as chlorine, strikes at the root of the trouble by breaking up the harmful substance and entirely removing it.

The acids formed by chlorine are:

Hydrochloric Acid	HCl
Hypochlorous Acid	$HClO$
Chlorous Acid	$HClO_2$
Chloric	$HClO_3$
Perchloric Acid	$HClO_4$

Bromine.—Br (At. Wt. 79.96). Is found in salt-beds and in salt-water in combination with sodium, potassium, and magnesium in the form of bromides. It is a heavy dark-red liquid and is easily vaporized. It owes its name to its disagreeable odor (Greek, bromos—a stench). It acts very like chlorine. It combines readily with other elements. Its compounds are called bromides. It forms hydrobromic acid with hydrogen (HBr), and bromic and hypobromous acids with oxygen.

Iodine.—I (At. Wt. 126.85). Is found in combination with sodium. Its chief source is the sea plants. The sea weed is burned and the iodine is obtained from the ash. Iodine is a grayish—black solid, volatile at ordinary temperature. Mixed with alcohol it forms the tincture of iodine of the druggist. When heated it changes into a violet vapor, whence it owes its name (Greek, iodos—violet). Its chemical behavior is similar to that of chlorine and bromine, but weaker. It turns ordinary starch-paste blue. Chlorine and bromine do not. This, then, is the test for free iodine. Its compounds, such as potassium iodide (KI), do not. The ordinary way of applying the test is to pourch lorine water, i. e., water in which chlorine gas has been dissolved, into the solution of the iodine salt, and then apply the starch test. The chlorine water sets the iodine free. It is said from this that chlorine has greater affinity for the metals than iodine has, because it takes the place of the iodine in compounds. It is also said for the same reason, that chlorine is a more stable substance than iodine. There is a hydriodic acid (HI) and an iodic acid (HIO_3).

Fluorine.—F (At. Wt. 19). Although this element is widely distributed in nature in a state of combination with other elements, it does not exist long in a free state, nor will it combine at all with oxygen. It is the only element that does not do so. Its most common forms in nature are, fluor-spar, or calcium fluoride (CaF_2) and cryolite or Iceland spar. Fluorine is the most active of all elements at ordinary temperatures. There is a hydrofluoric acid (HF), which is made from fluor-spar by the action of sulphuric acid. It is remarkable for its corrosive action upon glass. It is used for etching and writing upon glass. It must be kept in rubber or lead bottles. Its action upon glass is explained by its great affinity for silica which

is in glass and in all sand. The scales on the glass tubes of thermometers, barometers, etc., are etched by this acid.

THE SULPHUR GROUP.—These elements are sulphur, selenium and tellurium.

SULPHUR.—S (32.06). This element occurs in a free state in nature near volcanoes by which it is thrown up from the interior of the earth. The chief source of the sulphur of commerce is the volcanic region in the island of Sicily. Much sulphur is obtained from the ores of minerals, iron pyrites or iron sulphide; copper pyrites or copper sulphide; galenite or lead sulphide. When the ore is reduced part of the sulphur burns and part runs down to the bottom of the pile and runs off in a molten state. This sulphur is then refined, and comes into the market as roll sulphur and flowers of sulphur. The flowers of sulphur is produced by first vaporizing and allowing the vapor to condense. This process is called sublimation. The roll sulphur is cooled in molds of wood, which give it its shape. Sulphur is a pale yellow brittle solid. It behaves strangely under heat. It melts at 114.5° into a thin, light-yellow liquid; at from 200° to 250° it becomes quite dark in color and is gummy and elastic. In this form it is used for taking molds of coins, medals, etc. At about 450° it boils and turns into a brownish-yellow vapor. After it has been melted it will crystallize in yellow needle-shaped crystals of an eight-sided rhombic form. When sulphur unites with oxygen, which it does when it burns, it forms sulphur dioxide (SO_2), a gas with a pungent odor. This gas is much used for bleaching straw, for the manufacture of straw hats, etc. Sulphur combines with hydrogen and forms a gas of exceedingly disagreeable odor. The gas is hydrogen sulphide (H_2S). It is formed by acting on iron sulphide (F_2S) with sulphuric acid (H_2SO_4). It is formed in nature in the decaying of eggs. The odor of rotten eggs is partly due to the formation of hydrogen sulphide in the eggs. When the gas dissolves in water, as it readily does, it forms one of the most useful tests in the laboratory. It is used for testing for metals, as it forms with solutions of lead and other nitrates an insoluble sulphide of the metal which is thrown down.

Sulphur forms with hydrogen and oxygen several acids.

Hyposulphurous Acid	H_2SO_2
Thiosulphuric Acid	$H_2S_2O_3$
Sulphurous Acid	H_2SO_3
Sulphuric Acid	H_2SO_4
Diathonic Acid	$H_2S_2O_6$
Pyrosulphuric Acid	$H_2S_2O_7$
Trithionic Acid	$H_2S_3O_6$
Tetrathionic Acid	$H_2S_4O_6$

Sulphurous acid (H_2SO_3) forms the basis of the class of substances called sulphites.

Sulphuric acid (H_2SO_4) is the most important of the group of acids, and is one of the most useful substances known in the arts and manufactures. It is more difficult to manufacture than are other acids. The theory of its manufacture may be given by these equations.

1. Sulphur is burned in the air and sulphur dioxide is formed. $S+O=SO_2$.

2. The sulphur dioxide is combined with water-vapor or steam and sulphurous acid is formed. $SO_2+H_2O=H_2SO_3$.

3. The sulphurous acid is oxidized by compounds of nitrogen and oxygen and sulphuric acid is formed. $H_2SO_3+O=H_2SO_4$.

It is an oily liquid sometimes called the oil of vitriol. It unites with water readily and is used to dry gases, as when gases mixed with water-vapor are passed through sulphuric acid, the acid takes out the water-vapor. It chars wood and other vegetable matter. It is used in enormous quantities in the manufacture of sodium sulphate, sodium carbonate or washing soda, sodium bicarbonate or baking soda, fertilizers, nitro-glycerin, glucose, the refining of petroleum, etc. Sulphuric acid (H_2SO_4) differs from both hydrochloric acid (HCl) and nitric acid (HNO_3) in that it has two atoms of hydrogen. When salts of the metals are formed by the HCl and HNO_3, all of the hydrogen is replaced by the metal. In the case of sulphuric acid one or both of the atoms of hydrogen may be replaced. This makes two salts of each metal possible according to the number of atoms of hydrogen replaced. In the case of potassium (K) there may be either potassium sulphate (K_2SO_4), where the potassium replaces all of the hydrogen, or there may be the acid potassium sulphate ($KHSO_4$) where only one of the atoms is replaced by one of potassium. For this acids like hydrochloric and nitric, which have only one replaceable atom of hydrogen are called monobasic acids; and those like sulphuric, which have two replaceable atoms of hydrogen, are called dibasic acids. As dibasic acids form two classes of salts, those in which all of the hydrogen is replaced by the metal; and those in which only half of the hydrogen is replaced; the former are called the normal salts, and the latter the acid salts.

Sulphur unites with carbon to form carbon bisulphide (CS_2). These two elements unite at high temperature. Carbon bisulphide is a liquid which boils at the very low temperature of 47° C. It is a solvent of rubber, sulphur, etc., and is the basis of rubber cements. Selenium and tellurium are very rarely met with, either free or in combination. Their properties and chemical behavior are very similar to those of sulphur. Similar acids and compounds of these with other elements occur.

INDIA RUBBER

This interesting and useful substance is obtained from the sap of several varieties of trees which grow in Central America, the East Indies and the valley of the Amazon in South America. Most of the Rubber used in the United States is obtained from the Amazon region, where the largest variety of Rubber trees is found. The small Rubber trees that are sometimes seen growing in pots in this climate are of the same species as those of South America, but their growth has been dwarfed by the cold.

The sap of the Rubber trees is collected by the natives of tropical countries, in much the same way that we collect maple sap for making maple sugar. As it exudes from the incision made in the bark of the trees, the Rubber sap is a milky fluid and is so viscid that only a few ounces flow from a tree in a day. In the course of the collecting season, however, a large tree yields about twenty gallons of sap, from which forty pounds of Rubber are obtained.

To convert the sap into Rubber, it must be dried in the sun or over a fire. The latter method is most frequently used, and it is done by dipping a broad-bladed wooden paddle into the sap, and holding it for a few minutes in the smoke that arises from the fire; this operation is repeated as soon as a layer of Rubber forms on the paddle. In this way a ball weighing ten or twelve pounds is soon formed on the paddle, and in that form the Rubber is ready for market.

The manufacture of articles of all sorts from Rubber begins with the purification of the crude Rubber. For that purpose, the lumps of Rubber are first boiled for some time to soften them, and are then torn to shreds by cylinders armed with knives. The tearing is done in a stream of water that washes away the impurities and leaves the Rubber ready for the subsequent processes of manufacture, the nature of which is determined by the character of the articles to be made.

Formerly all Rubber articles were made from the pure Rubber, but now almost all the Rubber that we see has been treated by a process known as vulcanizing, by which its fitness for most purposes is greatly increased. This process consists in mixing the shreds of Rubber with varying quantities of sulphur, and heating it for varying lengths of time. By using a small proportion of sulphur and heating for a short time, soft Rubber is obtained, and by using a larger proportion of sulphur and heating for a longer time, hard Rubber is produced.

The uses to which Rubber is put are so numerous that many pages would be required for the mention of them; only a few, therefore, of the most important will be spoken of here. The use of Rubber in waterproof garments, for the tires of vehicles, for hose and belting, and to form the handles of implements, is, of course, well known; but there are two other extremely important uses of Rubber. One is its use by dentists to form the plates in which artificial teeth are imbedded, and the other is as an insulator for wires and cables which carry electric currents. The discovery of the process of vulcanizing Rubber almost revolutionized dentistry; and it made the construction of ocean telegraphs possible. Before the days of vulcanized Rubber, the plates for artificial teeth were made of gold, which was not only expensive, but hard to work into the desired form; and no insulating material used before the discovery of the vulcanizing process was capable of successfully resisting the corroding effect of sea water.

NITROGEN GROUP

The elements of this group are: Nitrogen, Phosphorus, Arsenic, Antimony, and Bismuth.

Nitrogen.—N (At. Wt. 14.04). This element and its properties have been dealt with under the article on Air.

Phosphorus.—P (At. Wt. 31). This element occurs in nature in the form of phosphates, the chief of which is calcium phosphates, found in bones, apatite, and phosphorite. Phosphorus is prepared by treating bones or bone ash with sulphuric acid, mixing the product with charcoal and heating. The free phosphorus is run into sticks, which process is performed under water. It is a colorless, translucent solid, so soft that it can easily be cut with a knife. It will not dissolve in water, but readily in carbon bisulphide. It is poisonous, even in the handling and inhaling. Those who work with it are frequently afflicted with phosphorus poisoning, one of the symptoms of which is the gradual decay of the bones. It takes fire easily even when exposed to the air.

MATCHES

The first attempts at devising some improvement on the clumsy flint and steel method of making fire, that had been in use since the Middle Ages, were made about the beginning of the 19th century.

A great many substitutes were invented, some of which were quite ingenious, but all the early ones were unreliable and some really dangerous. The first real improvement was brought about sometime between 1830 and 1840 by the use of phosphorus. The credit for this invention is thought to belong to a young Austrian mechanic, Johann Jrinyi, who hit upon the notion of using phosphorus from seeing it used in some experiments at a lecture.

Phosphorus is an element that is found in a considerable number of substances in nature, but that is never found uncombined. One of the commonest sources from which it is obtained is the bones of animals, in which it is always found in combination with calcium and oxygen. When extracted from bones, and obtained in the free state, phosphorus is a yellow, waxy substance, which must be kept under water and out of the light to keep it from undergoing chemical changes that completely alter its properties. When exposed to the air phosphorus gives off white fumes similar to those you see when a match is moistened and drawn across any object. These fumes are caused by the chemical action of the oxygen of the air upon the phosphorus, and if the latter is heated a little by rubbing it against something it suddenly takes fire and burns with great violence. This tendency of phosphorus to combine with oxygen so readily and so energetically is the property that makes it useful in match making. It also explains why that metal is never found free in nature, for whenever exposed to oxygen it combines with it, forming an oxide of phosphorus.

At the time when Jrinyi conceived the idea of using phosphorus in the manufacture of matches, little slips of wood that were tipped with sulphur, and that could be ignited in various ways, were in common use. He added a little phosphorus to the sulphur and the lucifer match was the result. The small amount of heat produced by drawing the match across a rough surface was sufficient to set fire to the phosphorus; the burning was passed on by the phosphorus to the sulphur, and from the sulphur to the wood. A very similar series of actions is brought about when we strike one of the matches used now, though the sulphur has been replaced by paraffin or stearin, a substance used for making candles.

In the seventy years that have passed since Jrinyi made his discovery the manufacture of matches has been the subject of constant study, and to-day there is scarcely an art that is more nearly perfected in every detail. At first, every operation in the process was performed by hand. The splints were cut, placed in racks, dipped in melted sulphur, set away on stands to dry, then dipped in the mixture containing phosphorus, set away to dry again, and finally re-

moved from the racks and boxed — all by hand. To-day it is no exaggeration to say that blocks of match wood are fed into one end of a match machine and matches boxed ready for sale taken out at the other.

In the most modern type of match-making machinery the match splints are cut from the blocks of wood by a row of punches, which move automatically back and forth across the block, removing a row of splints at every forward stroke. The punches not only cut the splints, but insert them into a long, endless belt or conveyer, which runs over the block of match wood, and which is provided with rows of holes to receive the splints as they are cut. If you examine an ordinary parlor match you can see at the butt end of it a slightly compressed portion where it was gripped by the conveyer. The splints are first carried by the conveyer to a tank containing melted paraffin, into which they are inserted to a depth of one-half or three-quarters of an inch. This saturates about one-fourth of the splint with paraffin and makes it burn more readily. In the old kinds of matches a sulphur bath was used instead of paraffin, but the paraffin answers the same purpose, and is free from odor when burning, so that now it is always used. The splints are next taken to the "heading tank," in which is contained the phosphorus mixture to form the heads. To apply the phosphorus to the ends of the splints various devices are employed. One very frequently used is a large rotating roller, the lower side of which is in contact with the mixture, which is of such consistency that it keeps the roller coated with a layer just thick enough to form the heads. The conveyer carrying the match splints passes above the roller and just close enough for the ends of the splints to come into contact with it. The phosphorus mixture is quite sticky and enough adheres to the end of each splint to form a head for it. The conveyer now travels a considerable distance to allow the heads to dry thoroughly, and finally passes in front of a row of automatic punches, which force the finished matches out of the holes in which they are held. The matches then fall into a hopper, from which they pass into the boxes automatically placed in position to receive them.

A great many more matches are produced in the United States in this way than in any other, but in recent years an increasing quantity of matches have been made with paper or cardboard instead of wooden splints. These matches are usually made in cards of half a dozen or more matches, and when one is wanted for use it is torn off the card.

In Europe little wax matches, or "vestas," are very much used. These are really very tiny candles with a little phosphorus mixture

on the ends for striking. They are rather more expensive than the wooden and paper matches, and on that account, perhaps, have never been manufactured in this country in large quantities.

The most important part of the match is the head, about the composition of which very little has been said. The essential part of the head, of course, is the phosphorus; but this must be mixed in the right proportion with a number of other substances in order to make perfectly satisfactory matches.

The heads of the ordinary parlor matches are composed of a small proportion of phosphorus, generally about one-twelfth of the whole mass, mixed with lamp black, glue, and some substance containing oxygen. The exact proportions in which these substances are mixed are generally kept secret by the factories and much care is bestowed on them as slight variations may do great damage. Too much phosphorus increases the cost of the matches; too little makes them uncertain in their action. A mixture that is too thin makes heads that are too small, and not enough heat is developed to set fire to the splints. When it is too thick, on the other hand, the heads of a number of matches run together, and when they are separated some may ignite and cause accidental destructive fires.

Ordinary matches are sources of two distinct kinds of danger. On account of the ease with which they ignite they are frequently the cause of destructive fires. Rats have been known to carry matches into their holes and there cause them to take fire and do great damage. The other danger from the use of matches is that of poisoning. Phosphorus, in its ordinary form, is one of the most deadly poisons, and absent-minded persons who stick matches in their mouths may suffer severely from their thoughtlessness.

It was to do away with both these dangers that the safety match was invented. You have doubtless seen such matches, and you may have wondered why they could not be ignited by striking them on any other surface than the one prepared for the purpose. The heads of these matches contain no phosphorus, but are composed of *sulphide of antimony* and *chlorate of potash*. The surface on which they will ignite is covered with a mixture of sand, glue, and a substance known as *red phosphorus*. This latter is obtained by heating common phosphorus in a vessel that contains no air. It is quite different in its properties from the common variety; it does not change in air, is not poisonous, and is much more difficult to ignite. The chlorate of potash in the match heads contains a large proportion of oxygen, and the heat developed by the friction of this substance on the red phosphorus is sufficient to ignite the sulphide of antimony and set fire to the match.

Matches of the kind just described are quite free from both the dangers of common matches, but their manufacture has never been extensively carried on in this country, the greater number being made in Sweden, and their use is by no means general.

Phosphorus unites with hydrogen to form phosphureted hydrogen (PH_3), it possesses the property of taking fire spontaneously when exposed to the air. When phosphorus burns in oxygen it unites with the oxygen and forms phosphoric pentoxide (P_2O_5). When this is dissolved in water it forms, according to the proportion of water, either metaphosphoric acid as in the equation: $P_2O_5+H_2O=2HPO_3$ or orthophosphoric acid $P_2O_5+3\ H_2O=2H_3\ PO_4$.

The latter is the ordinary phosphoric acid. As it forms three distinct salts with the same metal, having three atoms of hydrogen to replace it, it is a tribasic acid. Other phosphoric acids are: Pyrophosphoric acid ($H_4P_2O_7$), Phosphorous acid (H_3PO_3).

Arsenic.—As (At. Wt. 75). This element occurs in metallic ores which are the chief source of commercial arsenic. It is chiefly obtained by roasting arsenical iron pyrites (Fe As S), when the arsenic separates. It has the lustre of a metal. When heated before the blowpipe it gives off a strong odor like garlic. The metallic arsenic is not poisonous, the oxides are. Arsenic unites with hydrogen and forms arseniureted hydrogen (AsH_3). It is sometimes called arsine. It is important in the test for arsenic. The suspected liquid is placed in a flask with granulated zinc and dilute sulphuric acid is poured in. A delivery tube tending in a fine point is fitted to the mouth of the flask. Arsine is given off if arsenic is present. If not only hydrogen gas will be evolved. As both hydrogen and arsine are inflammable the escaping gas is lighted at the fine point of the delivery tube. It will burn with a pale light. A cold porcelain dish is held for a few moments in the tube, and if arsenic is present, it will be deposited upon the porcelain in a dark spot. This is called the mirror of arsenic. The test is known as Marsh's test, from the name of the discoverer. The substance which is usually termed arsenic is arsenic trioxide (As_2O_3). It is a glassy, colorless substance and very poisonous. The acids of arsenic are:

Arsenic Acid	$H_3As\ O_4$
Metarsenic Acid	$H\ As\ O_3$
Pyroarsenic Acid	$H_4As\ O_7$
Arsenious Acid	$H_3As\ O_3$

Antimony.—Sb (At. Wt. 120). It takes its symbol from the Latin name *Stibium*. It is a silver-white metallic element. It burns and unites with oxygen to form a white oxide (Sb_2O_3). Antimony unites with hydrogen to form antimoniureted hydrogen (SbH_3) or

stibine, which is very similar in its properties to arsine. The acids are very similar to those of phosphorus and arsenic.

Bismuth.—Bi (At. Wt. 208.5). This is a comparatively rare element in nature. It is a hard, brittle, reddish, metallic substance. It forms a yellow oxide with oxygen, when burned (Bi_2O_3). The subnitrate of bismuth is much used in pharmacy as a remedy for cholera and dysentery. It is also used in cosmetics.

Three very rare elements are similar to those of this group already mentioned. They are: Vanadium, Columbium, and Tantalum.

Boron.—B (At. Wt. 11). This element occurs in nature in the form of boric acid or as borax. Boric acid (H_3BO_3) issues from the earth in jets of steam, in Tuscany. These jets are called suffioni. The vaporized acid is condensed in tanks of steam. The other acids of boron are:

Metaboric Acid	HBO_2
Tetraboric Acid	$H_2B_4O_7$

Borax is a salt of tetraboric acid in which the two atoms of hydrogen are replaced by sodium. Its formula is $Na_2B_4O_7+10\ H_2O$.

THE CARBON GROUP

The members of this group are: Carbon, Silicon, and the rare elements, Titanium, Zirconium, Cerium, and Thorium.

Silicon.—Si (At. Wt. 284). This is one of the most abundant substances in nature. In the form of the oxide it makes up the greatest part of quartz and of sand. Silicon is the name given to the element and silica is the oxide (SiO_2). Clay is largely composed of silicon. It is never found in the free state, and it is hard to break up the oxide, which, however, may be done by heating it with potassium or magnesium. Crystals of silicon are harder than glass and are not affected by the strongest acids. When silicon unites with another element, silicides are formed. The most important of these is carbon silicide (CSi), which is made by heating quartz-sand, coke, and common salt in an electric furnace. It is commercially called carborundum, and on account of its extreme hardness it is used in the place of emery. The chief acids are:

Silicic Acid	H_2SiO_3
Polysilicic Acids	$H_2Si_2O_5$ and $H_4Si_3O_8$

One of these is the opal. Quartz, or rock crystal, is pure crystallized silicon dioxide. Glass is a combination of silicic salts and those of sodium, potassium, or calcium.

GLASSWARE

Glass-making, which has been mentioned as one of the arts in which soda is used in large quantities, is by no means a purely modern industry. On the contrary, it is one of the oldest arts practiced by mankind to-day. Beads of Glass, some of common clear Glass, and some very richly colored, have been found in the wrappings of mummies that were buried in the Pyramids of Egypt more than three thousand years ago. Glass lenses, thousands of years old; have also been found in the buried ruins of Nineveh, in the valley of the Euphrates and Tigris rivers.

Examination of these ancient pieces of Glass seems to show that they are made in much the same way in which similar articles are manufactured to-day. It is true that our modern tools and machinery enable us to make Glass much more rapidly, and with much less labor, than our ancestors did, and we use it for many purposes that were unknown to them; but, in the main, the Glass they made so long ago is the same as that made by us to-day.

All Glass consists of a mixture of certain substances called *silicates*, which are formed by the chemical combination of sand and certain metallic compounds, when these are fused together. Pure sand, the chemical name of which is *oxide* of *silicon*, or *silica*, is a compound of oxygen with an element called *silicon*. When *silica* is heated with certain compounds of some of the metals, they melt and combine chemically with the *silica*, to form compounds called *silicates*. The different kinds of Glass are mixtures of various *silicates*.

When sand is heated with soda or potash, the Glass formed is found to be completely soluble in hot water, and is known as "soluble glass" or "water glass," but when lime (*calcium oxide*), or red lead (*lead oxide*), is added to the mixture of sand and soda or potash, the Glass formed on heating is much less soluble and, in fact, is the Glass we use every day.

The uses to which Glass is put nowadays are so many and so different, that numerous varieties have been produced that have different properties and vary somewhat in composition. Sometimes the manufacturer's chief object is to make Glass very hard; sometimes it must be extremely soft; again perfect transparency and freedom from color are desired. In common bottle Glass and that which you see in skylights, cheapness is especially sought, and the maker puts into it the cheapest materials he can obtain.

It would take much too long a time to tell you how all the various kinds of Glass are made, and to describe the differences in their

properties; but there are two common varieties that are used in making most of the Glass articles with which we are familiar, and it is worth our while to know wherein they differ. These two kinds are "Crown Glass" and "Flint Glass."

Crown Glass is that used for windows, and may be either Common Blown Glass or Plate Glass. In making it, sand, soda, and lime or chalk are used. These are generally mixed with a certain amount of old, broken Crown Glass, which is called *cullet*. The addition of the *cullet* makes the other ingredients melt more easily.

Flint Glass differs in composition from Crown Glass, in containing potash instead of soda, and red lead instead of lime. It is sometimes known as Lead Glass. Flint Glass is not very hard, as you might think from its name. It is really much softer than Crown Glass. The name of Flint Glass was given to it, because the sand used in its manufacture is made by crushing flint.

The qualities of Flint Glass, that have caused its general use, are its transparency and its freedom from air bubbles. It is also readily melted, and this has led to its use in many ways, in which harder Glass could not be employed. It is more nearly free from all color than any other Glass yet produced, and for this reason it is employed in making lenses for spectacles, and other optical instruments, as well as for dishes, goblets, and other household articles.

The making of Glass is, in principle, a very simple matter, and one that is easily understood; but there are many details in its manufacture that require constant attention, and great skill and dexterity are absolutely necessary in handling it.

The first step in the manufacture of Glassware is the making of the Glass. For this purpose, a large furnace, with a number of small doors around it, is located in the center of the Glass-house, and in this furnace are placed a number of pots, or crucibles, as they are frequently called. Each of these crucibles can be easily reached, through one of the many small doors in the wall of the furnace.

After the crucibles have been *charged* with the sand, and other materials to be used, the furnace is heated to a very high temperature, and the mixture soon begins to soften into a pasty mass, which finally becomes a liquid that will flow like water. This gradual softening of the Glass is of the greatest value to the Glass-worker, for it enables him to mold the Glass into almost any form desired, before it becomes cold and hard.

Before the Glass in the crucibles becomes perfectly fluid, the workmen collect masses of it around the ends of long tubes, and, after

removing these from the furnace, they rapidly convert it into the shapes desired, by blowing, cutting, molding, bending, and twisting. The making of so common an article as an ordinary wine-glass requires a number of these operations, which are performed with wonderful quickness and are extremely interesting to see; but to describe them here would require too much space.

After the articles have been shaped by the workmen, they must go through another very important process before they are ready for the market. This is a very slow cooling, known as *annealing*. The object of it is to make the Glass durable, for Glass that has not been annealed is exceedingly brittle and easily broken. In carrying out the annealing process, the Glass is simply drawn very slowly through a long oven, one end of which is heated quite hot, while the heat decreases gradually toward the other end, which is only slightly warm. By this operation a change is brought about in the Glass, that makes it much less liable to break from slight blows.

Another method of treating the Glass, which makes it tougher even than does annealing, is to heat it for some time in oil. This method is known as the *De la Bastie method*, and the Glass treated by it is wonderfully tough, and will withstand remarkably heavy blows and shocks.

All Window Glass is now manufactured by one of two processes, one of which produces *Plate* Glass, and the other the common sort of Window Glass. These two kinds may always be distinguished by the difference in appearance. Plate Glass is made by pouring molten Glass upon large tables and rolling it out with heavy rollers until it is perfectly flat and of uniform thickness. The common Window Glass, however, is made by taking a ball of molten Glass from the crucible on a pipe, blowing it into a hollow cylinder, and then, before it has cooled, cutting the cylinder along one side and spreading it out into a sheet. By this method it is impossible to make the sheets so flat, and the thickness so uniform, as in Plate Glass, and, in consequence, objects are seen through Plate Glass with much less distortion, than through common Window Glass.

Thus far, nothing has been said of the production of the many beautiful colors that are found in various kinds of ornamental Glassware, without mention of which, our account of Glass and its manufacture, would not be complete. All of these colors are due to the addition to the materials used in making clear Glass, of small quantities of certain compounds, generally oxides, of a number of metals. These have the property of melting with the Glass, and of diffusing through it very readily, so that a small quantity of coloring matter is often sufficient to give a deep, rich color to a large quantity of

Glass. A red cólor in Glass is often due to the addition of gold, or in some cases of iron or copper compounds. Blue is produced by compounds of cobalt. The richest greens are obtained by using chromium, though some shades may be produced with copper. The beautiful amethyst or purple tint, sometimes seen in Glass, is due to the presence of manganese, and a very rich yellow is produced with uranium.

Titanium, Zirconium, Cerium, and Thorium are rare elements similar in properties and behavior to silicon.

Cerium.—A rather rare metal, resembling iron in color and luster, but soft, and both malleable and ductile. It occurs in the minerals cerite, monazite, allanite, etc. It takes fire more readily than magnesium, and burns with much brilliancy. It slowly decomposes cold water, and dissolves rapidly in hydrochloric acid. Its symbol is Ce, and its specific gravity is 6.7. Its atomic weight is 141, and its atomic value 21.0. Cerium was isolated and named by the chemist Berzelius, in 1803, after the asteroid Ceres, then but recently discovered. Combined with oxygen, it forms two oxides, and its oxalate is in certain cases a useful anti-emetic medicine. Being difficult to procure in a separate metallic state, it is not employed in the arts and manufactures.

POTASSIUM GROUP

Under this class are included Lithium, Sodium, Potassium, Cæsium, Rubidium, and Ammonium.

Potassium.—K (At. Wt. 39.15). This element is found in many of the minerals, in the ashes of plants. It is from wood-ash that the substance called potash is obtained by dissolving out the potassium carbonate with water. This is also called lye. The element potassium is a soft metal with a shining surface when freshly cut. Its action upon water is remarkable. When a small particle of it is thrown upon water, it breaks the water up into hydrogen and oxygen. The potassium unites with the oxygen, and the hydrogen is set free and burns with a violet light, which is the characteristic flame-color of potassium salts. When the potassium unites with the oxygen, an oxide is formed (K_2O). This unites with the water in the vessel and potassium hydroxide, or caustic potash, is formed (KOH). The formula is $K_2O+H_2O=2KOH$. This is a most useful substance in the laboratory. It is a white brittle substance usually in the form of sticks. It is one of the strongest of bases or alkalies. Potassium unites with iodine to form potassium iodide (KI) much used in medi-

cine; with the nitrate radical to form potassium nitrate or saltpeter (KNO_3); with the chlorate radical to form potassium chlorate, much used in medicine ($K\ ClO_3$), and with the carbonate radical to form potassium carbonate (KCO_3).

GUNPOWDER AND OTHER EXPLOSIVES

By Explosives are meant substances that can be made to give off a large quantity of gas in an exceedingly short time, and the shorter the time required for the production of the gas, the greater will be the violence of the explosion. Many substances, that ordinarily have no explosive quality, may be made to act as Explosives under certain circumstances.

Water, for example, has caused very destructive boiler explosions when a quantity of it has been allowed to enter an empty boiler that had become red hot. Particles of dust have occasioned explosions in sawmills, where the air always contains large quantities of dust. A flame, introduced into air that is heavily laden with dust, may cause a sudden burning of the particles near it, and, from these, the fire may be conveyed so rapidly to the others that the heat will cause the air to expand suddenly, and this, together with the formation of gases from the burning, will cause an explosion.

It must not be thought, however, that fine sawdust or water would ordinarily be classed as Explosives. The term is generally applied only to those substances that may be very easily caused to explode.

The oldest, and most widely-known Explosive that we possess is Gunpowder, the invention of which is generally credited to the Chinese. It is a mixture of *potassium nitrate*, or *saltpeter*, with powdered *charcoal* and *sulphur*. The proportions in which these substances are mixed vary somewhat in different kinds of powder, but they usually do not differ much from the following:

Sulphur..	10 per cent
Charcoal	16 " "
Saltpeter..	74 " "

The explosive quality of Gunpowder is due to the fact that it will burn with great rapidity without contact with the air, and that in burning, it liberates large volumes of gas. When a spark is introduced into it, the carbon, charcoal, and sulphur combine with a portion of the oxygen contained in the saltpeter to form *carbonic acid* gas, and *sulphurous acid* gas, and, at the same time, the nitrogen contained in the saltpeter is set free in the gaseous form. This action takes

place very suddenly, and the volume of gas set free is so much greater than that of the Powder that an explosion follows.

In the manufacture of Gunpowder all that is absolutely necessary is to mix the three ingredients thoroughly, and in the proper proportions. But to fit the powder for use in firing small arms and cannon it is made into grains of various sizes, the small size being used for the small arms with short barrels, and the large sizes for cannon. The reason for this is, that if the Powder is made in very small grains, it all burns at once, and the explosion takes place so suddenly that an exceedingly strong gun is required to withstand the explosion, while, if larger grains are employed, the burning is slower and continuous until the projectile has traveled to the muzzle of the gun. In this way, the projectile is fired from the gun with as much force as if the explosion had taken place at once, but there is less strain on the gun.

Powder of this latter kind always produces a considerable quantity of smoke, when it is fired, because there is a quantity of fine particles formed from the breaking up of the saltpeter and from some of the charcoal, which are not completely burned. This smoke forms a cloud that takes some time to clear away, which is a very objectionable feature. In order to get rid of it efforts were made to produce a substance that would explode without leaving any solid residue, and that could be used in guns. These efforts were finally successful, and there are now a number of *Smokeless Powders* in use.

The most satisfactory forms of Smokeless Powder are all made from Guncotton, or *nitrocellulose*. This substance, which is made by treating cotton with a mixture of *nitric* and *sulphuric acids*, is a chemical compound, not a mixture like Gunpowder; and when it is exploded it is all converted into gases, of which the chief ones are carbonic acid gas, nitrogen, and water-vapor. To cause the explosion of Guncotton it is not necessary to burn it, but a mere shock or jar will cause it to decompose with explosive violence. Of course, such a violent Explosive as this could not be used either in small arms or in cannon, but Guncotton can be converted into less explosive forms which are suitable for use in guns, and the majority of Smokeless Powders are made in this way. The methods used in producing the Smokeless Powders are kept secret by the various countries that use them.

Another very powerful Explosive, which is closely related to Guncotton, is *Nitroglycerin*. This compound is made by treating *glycerin* with the same sort of acid mixture that is used in making Guncotton. It explodes in the same way that Guncotton does and yields the same products. It is an oily liquid of yellow color, and on account of its

liquid form, it is difficult to handle and use. The difficulty in handling Nitroglycerin led to the plan of mixing it with a quantity of very fine sand, called *infusorial earth.* When mixed with this, a solid mass, called *Dynamite*, is formed, which is easier to handle and more difficult to explode, but which has almost as much explosive force as Nitroglycerin.

A more powerful Explosive than either Nitroglycerin or Guncotton is obtained by mixing them together. When this is done, the Guncotton swells up by absorbing the Nitroglycerin, and becoming a brownish, jelly-like substance that is known as *Blasting Gelatin.* This is generally considered the most powerful Explosive obtainable.

Let us now consider for the moment what it is that makes Guncotton, Nitroglycerin, and Blasting Gelatin explode so readily. The explanation is found in the presence in them of nitrogen. As you remember from what you learned about air, nitrogen is an extremely inactive element. It has no strong tendency to combine with other elements, and when it does enter into a combination with them, the compounds formed are almost always easily decomposed. In the compounds that have just been described, a shock causes a loosening of the bonds that hold the nitrogen, and the whole compound goes to pieces, just as an arch falls when the keystone is removed.

Potassium also unites with carbon and nitrogen to form potassium cyanide (KCN) a violent poison. Potassium sulphate (K_2SO_4) occurs largely in nature in the mineral kainite. Its uses are chiefly medicinal.

Sodium.—Na (At. Wt. 23.05). This element occurs abundant in nature in the form of sodium chloride or common salt (NaCl), in some silicates, in sea-shore plants, in the soil, in sodium nitrate, and in the mineral cryolite or Iceland spar. The element is a metal very similar in its action and properties to potassium. When thrown on water it acts like potassium, except that the hydrogen burns with the characteristic yellow flame of sodium salts. Sodium hydroxide (Na OH) is formed by the reaction. Sodium chloride (Na Cl) has been treated under chlorine (which see). Sodium hydroxide (NaOH) is commonly called caustic soda and is very similar to potassium hydrate. Sodium nitrate ($NaNO_3$) occurs in South America as Chili saltpeter. It is found as a crust upon the ground. Sodium sulphate (Na SO_4) is used in medicine under the name of Glaubers Salts. Sodium thiosulphate, or commonly hyposulphite of soda ($Na_2S_2O_3$+ $5H_2O$) is much used in photography where it dissolves the excess of silver on the plate after exposure. Sodium carbonate or soda (Na_2CO_3) is much used in the manufacture of other chemicals, glass.

SOAP

One of the chief uses of soda has been said to be in the manufacture of soap. Before we can properly turn our attention to the use of soda in soap making, we should know something of the manufacture of soda.

The making of soap is by no means a new art, though it has been greatly developed in modern times. History tells us that two thousand years ago the Germans made an ointment in substantially the same way that we now make soap, and that in A. D. 1000, there was a flourishing soap industry at Marseilles, in France. From there, the industry spread until it became known throughout all the civilized world.

Even before soap was manufactured, it was known that the ashes of some plants, when mixed with water, gave it a peculiar, smooth, slippery feeling, and made it better than ordinary water for cleaning. This was due to the presence of soda in the ashes, if obtained from seaweed, or, if from land plants, of a similar substance containing the metal potassium instead of sodium, and known as potash. Both soda and potash are very useful in cleaning, but they are injurious to the skin, and to the fabrics washed with them, so that soap serves the purpose much better.

To make soap, it is only necessary to boil together oil or fat and "caustic" soda, or potash. By caustic soda is not meant the sodium carbonate, but a substance made from sodium carbonate by adding slaked lime to a solution of it. The slaked lime, which will be discussed later, contains the metal calcium, in combination with hydrogen and oxygen, and its chemical name is *calcium hydrate*. When this is added to a solution of sodium carbonate, the sodium present combines with the oxygen and hydrogen to form a compound, variously called *sodium hydrate*, *sodium hydroxide*, or *caustic soda*. A similar compound of potassium is formed when slaked lime is added to a solution of *potassium carbonate*. In either case, the *calcium* is converted into *calcium carbonate*, which is not soluble in water and settles to the bottom; but the caustic soda or potash is dissolved.

The word "caustic" means burning, and when used in the terms caustic soda, and caustic potash, it carries that meaning. Both compounds will burn the skin severely, if allowed to remain on it even for a few minutes. This property was one of the first to be noticed, and it was from it that the substances just mentioned derived their names.

The fats used for making soaps consist of glycerin, in chemical combination with what are called fatty acids. When these fats are

boiled with caustic soda, or caustic potash, the fat is decomposed; the fatty acid combines with the sodium or potassium to form soap and the glycerin is left uncombined.

In modern soap factories the manufacture is carried on in large iron pots heated by steam. Some fat and oil is put into the pot and a little of a solution of caustic soda or potash, called lye, is added and the steam turned on. In a few minutes the fat and the lye combine and form a milky looking liquid. More lye is then added and the boiling is continued. This process is repeated until nearly all the oil or fat has combined with the lye. If yellow laundry soap is being made, some rosin is now put in, together with more lye, and this gives the yellow color. If toilet soap is being made, the rosin is omitted and a quantity of common salt is put in. The addition of the salt causes the water and the glycerin to separate from the soap, which rises to the surface and can be skimmed off. This is done as soon as the separation is complete, and the soap is then put on frames to harden partly before it is cut or pressed into cakes.

Soaps made in this way are the ordinary *hard* soaps. Soft soaps are made by treating fats with caustic potash, instead of caustic soda, and no salt is added to separate the soap from the liquid. As the water and glycerin do not separate from the soap, the whole mass remains of a soft consistency. Soft soap is also made with a lye, that is obtained from wood ashes by a process called "leaching." The ashes are placed in "ash hoppers," or barrels, and water poured upon them. The water trickles down through and dissolves the potash contained in the ashes, and a caustic lye is the result. This is in the form of a liquid, and is boiled with any grease or fat. The same liquid when boiled is sometimes sold in stores, under the name of concentrated lye.

Of the fats used in soap making palm oil is probably the commonest, but mutton suet, tallow, olive oil, cotton seed oil, and other fats are used, and the consistency of the soap depends somewhat on the kind of fat used as well as upon the lye. A soap made entirely from palm oil or tallow is very hard so that as a rule a little lard or hemp oil is added to soften it.

When it is desired to make soap heavy, it is boiled for a long time to cause it to take up water and thus to increase in weight. Sometimes other substances, that cannot be discovered by looking at the soap, are mixed with it, for the same purpose. Soft soaps, especially, are adulterated in this way, and the process is called "loading."

You have now learned the main facts in regard to the manufacture of soaps. The many different kinds that you see in stores are made in the way that has just been described, and the difference in

them is due to the addition of different perfumes and coloring matters, and sometimes, of antiseptics or medicines.

There is another carbonate of sodium, called monosodium, or primary sodium, carbonate ($H\ Na\ CO_3$). It is also known as sodium bicarbonate. It is used in medicine, cooking, soda-water and effervescent drinks.

AMMONIUM SALTS

THE chief of this group is ammonium chloride, or sal ammoniac (NH_4Cl). It is most abundant obtained from the gas-work. It is formed also when the hydrochloric acid and the ammonia bottles are placed mouth to mouth. Then it appears in the form of a white cloud. The reaction is $NH_3+H\ Cl=NH_4Cl$. It is much used in electric batteries.

Ammonium sulphide, $(NH_4)\ 2S$, is very similar in its action, odor, and other properties to hydrogen sulphide. It is a useful reagent in the laboratory.

Sodium-Ammonium phosphate ($HNaNH_4PO_4$) is also known as microcosmic salt, and is used in blow-pipe analysis in the laboratory.

LITHIUM.—Li (At. Wt. 7.03). Is the lightest metal known, and is found in some spring water. Its use is chiefly medicinal. Cæsium and rubidium are very rare elements

THE CALCIUM GROUP

THIS group includes Calcium, Barium, Strontium, and Glucinium.

CALCIUM.—Ca (At. Wt. 40). Is by far the most abundant of the series. It occurs in nature in enormous quantities. Limestone, marble, and chalk are all carbonates of calcium; gypsum is the sulphate; phosphorite and apatite are phosphates; and the fluor-spar is the fluoride of calcium.

In appearance it is a metal very similar to sodium and potassium, and, like them breaks up water when thrown upon it. It is a very active element and plays an important part in the economy of nature.

Calcium chloride ($CaCl_2$) is much used to absorb water, especially in drying gases in the laboratory.

Calcium oxide (CaO) is lime or quick-lime. Ordinary limestone is the carbonate of calcium ($CaCO_3$). When it is burned in the kiln, carbon dioxide (CO_2) is given off. $Ca\ CO_3+Heat=Ca\ CO_3-CO_2=CaO$.

Calcium hydroxide, $Ca(OH)_2$, is slaked lime, and is formed when water is poured on quick-lime (CaO).

Thus $CaO+H_2O=Ca(OH)_2$.

Calcium carbide (CaC_2) is formed when lime and coke (carbon) are heated intensely in an electric furnace. When water is poured upon it, acetylene gas is given off. (See ACETYLENE.)

Calcium hypochlorite, $Ca(OCl)_2$, is a constituent of "bleaching-powder" or chlorinated lime, $Ca(OCl)_2+CaCl_2$. It is commonly called "chloride of lime." When acted upon by an acid, it gives off its chlorine very rapidly. When exposed to the air, its chlorine is liberated by the action of the carbon dioxide (CO_2) of the atmosphere. Hence the chlorine is liberated very slowly in this way. It is a good bleacher, an antiseptic for the destruction of germs of disease and for preventing the slow decay of organic substances, by hastening their decomposition.

Calcium carbonate ($CaCO_3$). See LIMESTONE.

For the hardness of water caused by lime salts held in solution, see WATER.

Calcium sulphate ($CaSO_4$). See GYPSUM.

Calcium phosphates are:

Normal calcium phosphate	$Ca_3(PO_4)_2$
Secondary calcium phosphate	$Ca\,H\,PO_4$
Primary calcium phosphate	$Ca\,H_4(PO_4)_2$

These phosphates are very important factors in plant and animal growth. All plants need phosphates, and all animals require them to promote the growth of bone. When plants grow they contract a quantity of the phosphate from the soil. When animals eat these plants for food they get the phosphates which their growth requires. If the plants were allowed to decay upon the land they would give back the phosphate to the soil. Harvested crops are taken away and the land soon becomes exhausted. Phosphates must be put back in the form of fertilizers. Artificial fertilizers are made up of those substances which are rich in phosphates. These are bone-ash, the mineral phosphorite, guano. Superphosphate of lime, is a mixture of soluble phosphate and of calcium sulphate.

For the uses of calcium silicate in glass-making, see GLASSWARE.

When limestone contains a large proportion of magnesium carbonate and aluminum silicate they form a product which becomes very solid and are what are known as cements.

The flame reactions of calcium, barium, and strontium are most marked. Calcium salts color the flame a reddish yellow; barium, yellowish green; and strontium, intense red. These are therefore much used in fireworks, colored flames, and colored glass.

THE MAGNESIUM GROUP

The members of this group are: Magnesium, Zinc, and Cadmium.

Magnesium.—Mg (At. Wt. 24.36). This element is found in many minerals, such as dolomite, carmallite, magnesite, serpentine, meerschaum, asbestos, and hornblende. It is a silver-white metal which burns with an intense flame known as magnesium-light, much used for flashlight photography, when it is burned in the form of powder.

Magnesium oxide, or magnesia (MgO); magnesium chloride ($MgCl_2$); magnesium sulphate or epsom salts ($MgSO_4$); and magnesium carbonate ($MgCO_3$) are the chief compounds of magnesium. The sulphate occurs in Germany as the mineral kirserite. It is used as a purgative medicine, and in the manufacture of fertilizers, chemicals, and as a dressing for cotton goods.

Zinc.—Zn (At. Wt. 65.4). Occurs in mineral form as a zinc carbonate or smithsonite ($ZnCO_3$); the sulphide, or spalerite (ZnS); and the silicate ($ZnSiO_4$). These ores are easily roasted to form the oxide of zinc, and the oxygen is then removed by burning with charcoal. In this process the zinc turns to vapor and solidifies in the form of zinc dust. It is then condensed into a liquid and is run into plates. In this state it contains impurities of lead, iron, arsenic, and cadmium. It is then known as spelter. It may be purified by repeated distillation. It is a bluish-white metal. It is brittle at ordinary temperatures; is soft enough to roll into plates at from 100° to 150°; is brittle again over 200°; melts at 433°; and boils at 1040°. Iron covered with zinc is galvanized iron; mercury mixed with zinc forms mercury amalgum. Zinc also helps to form brass. Zinc oxide (ZnO) turns yellow on being heated, turns white again on cooling. It is used in ointments in medicine, and goes to form the paint known as zinc white.

Zinc sulphate ($ZnSO_4$) is called white vitriol. It is largely formed in galvanic batteries as the zinc plate is acted upon by the acid.

COPPER GROUP

Copper, Mercury, and Silver are the elements of this group.

Copper.—Cu (At. Wt. 63.6). Occurs native around Lake Superior and in Japan, China, Siberia, and Sweden. When combined with oxygen it forms ruby copper; with sulphur, chalcocite; with sulphur and iron, copper pyrites. It is a hard metal with a reddish color.

When exposed to the air it accumulates a green layer of a carbonate of copper known as verdigris. Nitric acid dissolves it, forming green copper nitrate, $Cu(NO_3)_2$; hydrochloric acid does not affect it; sulphuric acid dissolves it when heat is applied, forming the sulphate ($Cu\ SO_4$). The commercial uses of copper are extensive: coins, electrical apparatus, copper vessels, covering of roofs and the bottoms of vessels, etc., copper-plating, and a number of alloys.

Brass is one part zinc to two parts copper.

Pinchbeck is copper, zinc, and tin in varying proportions.

Bronze is copper, zinc, and tin in varying proportions. It is largely used for house and church bells, cannon, speculum, and telescope metal. Silico-Bronze and Phosphor-Bronze have silicon and phosphorus mixed with the bronze and are used to conduct electricity. Manganese Bronze is used for making screw-propellers.

Gun-metal is 100 parts copper to 11 parts tin.

Bell-metal is gun-metal with a large proportion of tin.

Aluminum Gold is copper with from 5 to 10 percent of aluminum.

German Silver is copper, zinc, and nickel.

Brittania Metal is generally composed of 90 parts tin, 8 parts antimony, and two parts copper. It is largely used as a basis for electroplate.

Copper has two valences or combining powers; hence there are two series of compounds. Its low combining power gives cuprous salts; its high valence gives cupric salts.

There are two chlorides, cuprous chlorides ($CuCl$), and cupric chloride ($CuCl_2$).

Cuprous oxide (Cu_2O) is ruby copper.

Cupric oxide (CuO).

Copper sulphate ($CuSO_4$) is called blue vitriol. It forms large blue crystals. It is used for making blue and green dyes and paints, in copper-plating, in galvanic batteries, and for preserving wood.

Copper-plating consists in placing the object to be plated in a solution of a copper salt, such as copper sulphate, in a bath and connecting it with one pole of an electric battery. The copper salt is broken up and the metallic copper is placed in an even layer all over object.

Mercury.—Hg (At. Wt. 200.3). Occurs native in combination with sulphur, as cinnabar (HgS). Sometimes it is found in drops among crevices in rocks. It is a silver-white heavy liquid. It freezes at about 40° below zero. It is 13½ times heavier than the same volume of water. It is used in thermometers and barometers. It is mixed with tin to form the amalgam with which the backs of mirrors are

coated, and it is used in the recovery of gold and silver from their ores. The compounds of metals with metals are called alloys. The compounds of mercury with metals are called amalgams. Both alloys and amalgams are only mechanical mixtures and are not chemical combinations. There are two classes of mercury compounds, the mercurous and the mercuric; due to the fact that mercury has two valences. Mercuric oxide, or the red oxide of mercury (H_9O), may be separated into metallic mercury and oxygen gas by the application of heat. It was by heating this substance that oxygen was first discovered.

Mercurous Chloride (H_9Cl) is the substance known as calomel and is extensively used in medicine.

Mercuric Chloride (H_9Cl_2) is known as corrosive sublimate. It is used as an insecticide, germ-killer, and aseptic treatment of wounds, and surgical instruments.

Silver.—Ag (At. Wt. 107.93). Occurs native, but the greater quantity is obtained from galenite, a sulphide of lead (PbS). It has proven a difficult matter to separate the silver from the lead. One method is Patterson's. By it the mixture is first melted and on cooling crystals of almost pure lead separate. They are dipped out. On standing longer these are removed as before. This is continued as long as possible. The residue is silver with some lead. This is all heated again in the air; the lead oxidizes and is washed out, leaving pure silver. By the zinc process or Parkes's method, the galenite is melted with zinc, which takes up all of the silver. The zinc is oxidized by superheated steam and the silver remains pure. By the amalgamation process, the ores are mixed with common salt and roasted. The silver forms with the salt, the chloride of silver. This is heated with iron, when the silver separates. It is collected by means of mercury, as the silver forms an amalgam with it, while the iron chloride will not. The amalgam is heated in a still and the mercury distils over leaving pure silver. Silver is not acted upon by air, oxygen, or water. Sulphur turns it black, forming the silver sulphide. Hydrochloric acid will not dissolve it, but concentrated sulphuric or dilute nitric will. The silver of coins contains between 7 and 10 per cent of copper. Plating with silver is the same process as with copper.

Silver nitrate ($Ag\ NO_3$) is known as lunar caustic. It is formed when silver is dissolved in nitric acid. Silver is much used in photography.

THE CHEMISTRY OF PHOTOGRAPHY

It has long been known that when certain chemical compounds, namely the chloride, bromide, and iodide of silver, are exposed to the light, they undergo a change that causes them to darken. This change forms the basis of Photography, as it is practiced to-day. Glass plates and strips of celluloid, that are coated with a thin layer of gelatin containing a quantity of bromide of silver, form the photographic plates and films, which the photographer exposes to the action of light in his camera.

After the exposure, no change can be seen in the plate; but if it is removed from the camera without being again exposed to the light, and is then treated in a "dark room" (one lighted with weak red light only) with certain substances known as *developers*, an image will appear on the plate, in which the dark parts correspond to the bright parts in the object photographed. On account of this last peculiarity, the image is called a negative. The image on the plate is formed by the decomposition of metallic silver at the points where the light acted on the plate. This is the result of a chemical change that takes place in the silver bromide, when the plate is exposed.

Just what the nature of the change is has not been discovered; but we know that a change takes place, for silver bromide that has been exposed to light is easily decomposed by developers, while silver bromide that has not been so exposed is unaffected by them. Since the greatest change in the silver bromide occurs at the points where the light is strongest, the greatest deposits of silver on the plate, and the darkest parts of the image, must correspond to the brightest parts of the object.

After the image has been fully developed, the unchanged bromide of silver on the plate must be removed, or the whole plate will darken as soon as it is exposed to the light again. The removal of the unchanged silver compound is accomplished by soaking the plate in a solution of hyposulphite of soda. This dissolves the bromide of silver and fixes the image. If, however, any of the hyposulphite of soda is left on the plate, other changes will follow that will finally destroy the image, so the plate must now be washed in water until every trace of hyposulphite is removed. It is then dried and used for printing.

In printing from a negative, a piece of paper having some compound of silver on its surface is placed under the negative, and is exposed to the action of the light. An image then forms upon the paper, in which the dark parts correspond to the light parts of the

negative, that is to the dark parts of the object photographed, for the image is now reversed a second time.

The image formed in this way is not permanent, for if we continue to expose it to light, the whole surface of the paper will darken, and the image will disappear. To prevent this, the image must be fixed, as was done with the one on the plate, by soaking in hyposulphite of soda, and finally washing the paper to remove the hyposulphite. An image that is tolerably permanent will be formed in this way; but it is of an ugly, yellowish color that is not at all desirable. If, however, the print is put into a weak solution of chloride of gold, after the fixing is complete, the gold will replace the silver in the image, and will cause its color to change from the undesirable tint first obtained, to a rich purplish brown. This process is called *toning*, and besides improving the appearance of the picture, it makes it more lasting, for an untoned print will always fade gradually, while one that has been properly toned is quite permanent.

THE ALUMINIUM GROUP

The members of this group are: Aluminium, Gallium, Indium, Thallium, Scandium, Yttrium, Lanthanium, and Ytterbium.

The only common member of the group is aluminium, Al (At. Wt. 27.1). It is among the most important and widely distributed elements. It occurs in feldspar, granite, mica, and cryolite. It is abundant in clay, kaolin, and all soils. Aluminium is destined to be a most useful metal. Its specific gravity is only 2.5; iron is 7.8; silver, 10.7; led, 11.37; and tin, 7.3. It does not change in water, hydrochloric acid easily dissolves it. Aluminium oxide (Al_2O_3) occurs in the form of the ruby, sapphire, and corundum. In the form of emery it is much used for grinding and polishing. Aluminium hydroxide, $Al(OH)_3$, and aluminium silicate are common compounds. Alums are compounds of aluminium sulphates with sulphates of potassium, soldim, and ammonia. Kaolin is the purest form of aluminium silicate found in nature. When it is mixed with feldspar it melts and forms porcelain.

EARTHENWARE

If the art of Glass manufacture can boast of great age, this is certainly none the less true of Earthenware and pottery. In the far Eastern nations of China and Japan, the art of making porcelain was

developed long before the beginning of the Christian era, and it is questionable whether any of the Earthenware produced in the world to-day is equal in beauty to some of that produced thousands of years ago. Modern improvements in the art have resulted in cheaper methods of manufacture, and all kinds of Earthenware are now produced in much greater abundance. Some of the colors imparted to their porcelain by the Chinese and Japanese of long ago, however, seem beyond the skill of modern manufacturers.

Earthenware, as you already know, and as the name indicates, is made for the most part of earth, or, to speak more accurately, of clay. The peculiar property of clay that renders it fit for use in this way is the readiness with which it can be converted into a paste by mixing with water, and with which this paste can be converted by heat into a hard, solid substance, that is no longer acted upon by water. While in the pasty condition, the clay is molded into various shapes with as much ease as mud pies are made, and when the clay is heated, these shapes are made permanent.

All clay consists mainly of a silicate of the metal *aluminium*, and it is this compound that is of most value to the maker of Earthenware. When the clay is almost pure silicate of aluminium, it is white in color and is known as *kaolin*. This is used in making the finest grades of china and porcelain. Other clays, such as potter's clay, pipe clay, and blue clay, are mixtures of aluminium silicate with various substances, that can be melted with comparative ease. Kaolin will not melt, and in making china it is necessary to mix with the kaolin a certain quantity of other material, to form what is called a *flux*. This flux softens in the furnace and binds the particles of kaolin firmly together.

After the Earthenware has been baked, or *fired*, to use the technical term, the clay is fixed in shape, and is no longer acted upon by water; but the surface is slightly rough and somewhat porous. If moistened when in this condition the surface changes color, because the water soaks into it. To make the vessels more suitable for holding liquids, it is necessary to make the surface nonporous and perfectly smooth, by giving it what is called a *glaze*. This is done in fine china by drawing the vessels slowly through tanks of water, in which have been mixed some kaolin and a larger proportion of the same kind of flux that was used in the original manufacture of the vessels. A thin layer of flux, together with a little kaolin, is thus deposited on the outside of the vessels. When they are put into the furnace and fire again, this layer melts, and, on cooling, forms the smooth, glazed surface, that we are accustomed to see on china and porcelain.

In the cheaper forms of Earthenware, such as earthen jugs, jars, and sewer pipe, the glaze is often imparted by simply sprinkling on the surface of the vessels, while in the furnace, some substance that will cause the materials on the outside to melt and run together, so as to close the pores. Sometimes these materials are mixed with the clay of which the vessels are made. Common salt, borax, sand, and oxide of lead are some of the substances used for this purpose.

When china is painted or gilded with the paints used in ordinary printing on wood, paper, or cloth, the figures are apt to disappear at the first washing. In order to make the colors permanent, the paint is made by mixing the metallic compounds that form the colors with some flux like that used in the manufacture of china. After the painting has been done, the vessels are again fired and the colors *burned in*, that is, the flux melts and forms a kind of glaze on the surface of the china.

Clay is an aluminium silicate. It is colored according to the quantity and kind of iron hydroxides which are present. The better varieties are used for making Earthenware, bricks, etc.

Marl is clay with a great admixture of calcium carbonate. Ultramine was formerly made by powdering the substance called lapis lazuli, which is a compound of aluminium, sodium, and sulphur. It is made artificially by melting kaolin, sodium carbonate, and sulphur; or clay, sodium sulphate (calcined), and charcoal. The artificially made is a richer color than the native.

THE LEAD GROUP

Lead, Tin and Germanium.

Lead.—Pb (At. Wt. 206.9). The most important source is galenite or lead sulphide (PbS). The method of extraction has been described under silver. Lead is a very soft, weak metal. It melts at 325°. Its compounds are highly poisonous. It is soluble in nitric acid; but not in hydrochloric or sulphuric. Lead oxide (PbO) is known as litharge. When heated to 400°, it takes up more oxygen and becomes red lead or minium (Pb_3O_4). Lead peroxide (PbO_2) and lead suboxide (Pb_2O) are other compounds with oxygen.

Lead acetate, $Pb\ (C_2H_3O_2)_2$, is called sugar of lead. It is formed by dissolving litharge in acetic acid. It is much used in medicine.

Lead carbonate ($Pb\ CO_3$), is white-lead and is used as a paint.

Tin.—Sn (At. Wt. 118.5). This element occurs in nature as the mineral cassiterite, which is the oxide of tin (SnO_2). The purest

tin is Banca tin from Banca in the West Indies. Block-tin from England is also pure. It is a white silver-like metal; it can be hammered into thin sheets called tin-foil. The air has no effect upon it. What is usually called tin in the various articles of tinware is a coating of tin upon thin sheets of iron. It forms several alloys. Those with copper have been described under that head.

Soft solder is either equal parts of tin and lead, or one of lead to two of tin.

Britannia metal is nine of tin to one of antimony.

Tin amalgam is a mixture of tin and mercury used for mirrors.

THE IRON GROUP

Iron, Cobalt, and Nickle form this group.

Iron.—Fe (At. Wt. 56). Is beyond doubt the most useful metal.

IRON AND STEEL

The extraction of iron from the substances in which it is found in nature is by no means a recent achievement; but the methods now employed for that purpose, and the scale on which iron manufactures are now carried on, are very different from what they were in the past. Then iron played only a small part in the daily life of mankind, whereas now it is used more than all the other metals together. Some one has said that the chief difference between the present age and the ones that preceded it lies in the wider use that is now made of iron.

As found in nature iron is always in combination with some other substance, generally oxygen. The compounds that it forms with oxygen are quite numerous, and they make up the bulk of the valuable iron ores. The word ore means the natural form in which the mineral occurs.

In principle, the extraction of iron from its ores is a very simple matter; all that is necessary is to heat the ore strongly in the presence of some form of carbon. The oxygen in the ore combines with the carbon to form carbon monoxide, and the iron is set free. The change may be represented thus:

Iron oxide + carbon = iron + carbon monoxide.

This is not an exact statement of what takes place, however, for the iron produced is not pure. It always has mixed with it a certain

quantity of carbon, and the properties of the resulting iron are largely dependent upon the proportion of carbon present. Iron is divided into the following three classes, according to the amount of carbon contained in it:

Pig, or *cast iron*, containing from four to five per cent of carbon.

Steel, which contains less carbon than pig iron, but more than the wrought.

Wrought iron, containing about one-half per cent of carbon.

Pig iron is easily melted and can be cast, but it cannot be worked in the forge; steel can be cast, and can also be worked in the forge, and the articles made from it can be tempered; wrought iron cannot be cast, but can be worked in the forge, though articles made from it cannot be tempered afterward.

The first form of iron produced was wrought iron. This is the only kind that can be produced without a very hot furnace, because iron does not take up much carbon except at very high temperatures. The early iron workers had no way of making very hot fires, but they had learned that when air was forced up through a fire more heat was produced than when it burned on the ground, and their forges were built with some form of bellows that could be used for this purpose. This gave sufficient heat to extract iron from some of its ores, but others could not be successfully treated in an open forge, because the fire was not hot enough. To remedy this defect chimneys were built around the forges, and the heat that had been wasted on the surrounding air was kept in the forge. The stones in the chimney took up the heat, and became so hot that the refractory ores were reduced and the iron liberated. The temperature of the furnace was also made high enough to make the iron take up four or five per cent of carbon and then to melt, thus forming pig iron.

At the present day the first stage in the manufacture of any kind of iron is to make pig iron. This is done in enormous furnaces, and the process is called smelting. Before attempting to understand this process you should learn something about the furnaces in which it is carried on.

They are tall structures of brick or iron that look like very broad chimneys. At the bottom there are generally two or more doors, and there is a track running to the top for carrying the iron ore, the fuel, and the other substances used in the smelting process. Large pipes enter the bottom, to carry the air that is forced up through the fire in the furnace to produce greater heat. These pipes are known as *twyers*, and the air forced through them is called the *blast*, from which we get the name *blast furnace*, which is applied to furnaces of this kind.

When one of these furnaces is to be put in operation it is "charged" with successive layers of fuel, ore, and a mixture formed of such substances as lime, clay, and sand, about which you will learn more presently. The fire is then started, and the blast is turned on, and it is kept going day and night until the furnace is "burned out." As the mass in the furnace settles downward more fuel, ore, etc., are added, and the smelted iron drawn off at the bottom. The furnace is not allowed to go out, because the cooling would cause its fire-brick lining to crack, and one of these linings can be replaced only at considerable expense.

Let us now turn our attention to the process that goes on in the furnace. When the heat becomes sufficiently great, the iron oxide is decomposed by the carbon of the fuel and the iron is set free and sinks toward the bottom of the furnace. As it goes downward, it keeps getting hotter, until it takes up enough carbon to cause it to melt; but after that has happened the iron has to pass the point where air is blown into the furnace, and there it would be burned to iron oxide again were it not for the mixture of sand, lime, clay, etc., that was put in with the ore and fuel. These substances melt and form what is called *slag*, a kind of glass, which covers the particles of molten iron, and protects them from the effects of the air blast. Lower down in the furnace the heavy iron separates from the lighter slag, and settles to the bottom, leaving the slag floating on the surface. This permits the iron and slag to be drawn off separately, through different doors.

When the iron comes from the furnace it is so hot that it is a liquid almost as thin as water. This causes it to flow very easily along grooves that are formed in sand to receive it. It hardens in these grooves, forming heavy solid blocks called *pigs*. The central groove from which the smaller ones branch off, is called the *sow*.

The iron produced in this way is very hard, brittle, and easily melted. These properties make it unsuitable for use where it would receive heavy blows, but it can be readily cast into various forms, and is, therefore, used for making stoves, grates, and many other articles of hardware.

Since the difference between pig iron and the other forms of iron is that the former contains a larger percentage of carbon, it is evident that if a portion of the carbon were burned away steel would first be formed, and then wrought iron. It is almost impossible to burn away just enough carbon to leave steel, however, so, in converting pig iron into the other forms, it is first changed into wrought iron, by burning away nearly all the carbon, and then converted into steel, by causing it to take up just enough carbon for the purpose.

Cast iron is converted into wrought iron by a process called *puddling*. This consists in heating the cast iron in what is called a *reverberatory furnace*, the peculiarity of which is that in it the flame from the fire comes into direct contact with the iron. In puddling, the carbon of the cast iron is burned out, and wrought iron is left. During this process the iron is raked back and forth (puddled) over the hearth of the furnace in order to bring all of it into contact with the flames, and when this has been done long enough the iron is formed into lumps or balls, which are then hammered or squeezed to get rid of any slag that may have become mixed with the iron.

Great heat is required to melt iron produced in this way, but it becomes soft and pasty when heated sufficiently, and while in this condition can easily be hammered into different forms. It is because this iron can be worked in this way that it is called *wrought iron*. It is not hard and brittle, like cast iron, but is tough and malleable. It is easily bent, but is very hard to break. Another important property of wrought iron is, that it welds or unites, when two pieces of it are heated until they become pasty, and are then hammered together.

Steel was formerly made almost entirely by packing bars of wrought iron in an iron box with charcoal and heating them intensely for a week or ten days. By this method, which is called the *cementation process*, the iron bars were caused to take up a certain amount of carbon and thus become changed into steel. On account of the peculiar blistered appearance of the bars after this process the steel made by it is called *blistered steel*.

The cementation process is still employed to some extent in steel making, but it is very slow, and has been largely replaced by what is known as the *Bessemer process*. By the Bessemer process, which is named after its inventor, steel is made in from twenty to thirty minutes, instead of a week or ten days, as in the cementation process. Molten cast iron is poured into an egg-shaped vessel of boiler iron, lined with fire-brick, which is called a *converter*. Air is forced up through the molten iron from the bottom of the converter, and after twenty or thirty minutes the carbon is entirely burned out. If the contents of the converter were now poured out they would be practically useless, but at this point enough pig iron is thrown into the converter to supply the mixture with just enough carbon to convert it into steel.

The pig iron added to the contents of the converter is generally of the kind known as *spiegel eisen* (sparkling iron), which contains a small amount of an element something like iron, and known as *manganese*. This element is thought to produce a desirable effect upon the steel.

Steel has thus far been spoken of as lying between the two other varieties of iron, and as differing from them only in the amount of carbon contained in it. This is not exactly true, for steel has been made that contained as much carbon as some cast iron; and, on the other hand, it sometimes contains as little as wrought iron. There is a hidden difference between steel and the other forms of iron, which is not fully understood, and which seems to be independent of the amount of carbon present. This difference is said to be one of structure. The particles of steel are thought to be held together in a different way from those in cast and wrought iron.

The most characteristic property of steel, perhaps, is its capacity to receive temper. When steel is heated quite hot, and is then cooled suddenly, it is hardened and made more elastic; this is called *tempering*, and the increase in hardness and elasticity produced in this way is called *temper*.

Besides the methods that have been described for the manufacture of iron and steel, there are many others that have been devised especially for certain kinds of ore, or with a view to the production of iron or steel having special properties. The processes already explained are of more general interest, however, and will enable you to understand the others as you will find them described in books devoted especially to this subject.

As iron has two valences, it forms two classes of compounds, the ferrous and the ferric. Ferrous compounds are converted into ferric by oxidation, that is the addition of more oxidation. Ferrous hydroxide $Fe(OH)_2$ will turn into ferric hydroxide $Fe(OH)_3$ on mere exposure to the air.

Ferrous Sulphate or Copperas ($FeSO_4$).—It is known also as green vitriol and is obtained by dissolving iron in dilute sulphuric acid. On a large scale, copperas is also obtained from iron pyrites, the mineral ferric sulphide, which oxidizes readily in the presence of moisture. It forms double salts with the sulphates of potassium and ammonium. Copperas is used in the arts in the dyeing of black fabrics and in the manufacture of ink; it is also an ingredient of some medicines. It is composed of 25.7 per cent of protoxide of iron, 28.9 per cent of sulphuric acid, and 45.4 per cent of water.

Ferric oxide (Fe_2O_3) occurs in nature as hematite, or red iron ore.

Iron pyrites (FeS_2), or fool's gold, is a yellow crystalline form very abundant in nature.

Nickel.—Ni (At. Wt. 58.7) is much used for coins and for plating. The coins of the United States contain one part nickel to three of copper. Nickel salts are green.

Cobalt.— Co (At. Wt. 59). The salts of this element are red when dissolved in water and blue when dried. A dilute solution of cobalt salts may be used to write with as ink. The writing is invisible until the paper is heated when the writing turns first blue and then red. On cooling the colors fade again entirely and the writing becomes invisible. These salts form the basis of the so-called sympathetic inks.

THE MANGANESE GROUP

In this are included Manganese, Chromium, and Uranium.

Manganese.— Mn (At. Wt. 55). This element occurs most abundantly in the form of the dioxide or black oxide of manganese (MnO_2). It has two valences and consequently forms two series of salts, the manganous and the manganic.

Manganese dioxide (MnO_2) is called pyrolusite. It is used in the preparation of chlorine and oxygen. It has the effect of decolorizing glass. Glass has naturally a green color, the manganese would color clear glass amethyst. But the two colors antagonize one another and clear glass results.

Chromium.— Cr (At. Wt. 52.1). This is a rare element. It forms the compounds, potassium chromate ($K_2Cr\ O_4$), and potassium diochromate ($K_2Cr_2O_7$). Both of these are good oxidizing agents. This means that they take up oxygen easily and give it up easily. They are good carriers of oxygen.

Chromium (Greek, *chroma*, color).— A metal, known to mineralogists as red-lead, a compound of chromium with lead and oxygen. Its most abundant ore is chrome iron, a compound of its oxide with oxide of iron. For commercial purposes it is manufactured by subjecting chrome iron (previously reduced to a fine powder) to a strong heat, with a mixture of carbonate of potash and nitrate, in a reverberatory furnace. After a lengthy process of fusion, the resulting mass is broken up and treated with boiling water, when chromate of potash is dissolved out. By a further process, the chromate is converted into bichromate of potash ($K_2O_2Cr\ O_3$).

In addition to the ordinary alum, and the iron alum there is also a chrome alum, which differs from the ordinary alum by having chromium in place of aluminum. The formulas of the three alums are:

Ordinary Alum	$Al\ K\ (SO_4)_2$
Iron Alum	$Fe\ K\ (SO_4)_2$
Chrome Alum	$Cr\ K\ (SO_4)_2$

Uranium.— U (At. Wt. 239.5). Occurs mostly in the form of the oxide (U_3O_8) called pitchblende.

THE PLATINUM GROUP

THIS includes Platinum, Osmium, Iridium, and Gold.

PLATINUM.— Pt (At. Wt. 194.8). This element occurs in the Ural Mountains, in California, and in Australia. It is usually alloyed with iridium, halladium, rhodium, ruthenium, and osmium. The alloy is dissolved in aqua regia, the mixture of nitric and hydrochloric acids which alone is capable of dissolving gold and platinum. From the solution chlorplatinic acid results ($H_2Pt\ Cl_6$). This acid is treated with ammonium chloride (NH_4Cl) which throws down a compound $(NH_4)_2Pt\ Cl_6$, this is heated and the platinum is left behind.

Platinum is a grayish-white metal, and is one of the heaviest substances known, as it has a specific gravity of 21.15. Iron has only 7.8 and lead 11.4. It is the most difficultly fusible metal known, and is therefore used for making crucibles and wire to stand the highest temperature.

Chlorplatinic acid ($H_2Pt\ Cl_6$) is formed when platinum is dissolved in aqua regia. It is used as a test for potassium.

GOLD.— Au (At. Wt. 197.2). Occurs native in quartz or in quartz sand. It is found in California, the Western States of America, Australia, Hungary, Siberia, Africa, and Alaska. Gold mining is either placer-mining or vein-mining. In placer-mining the sand containing the gold is washed away in pans, leaving the heavier gold and other minerals behind. These are allowed to flow over mercury, which takes up the gold only. The result is distilled and separated. In vein-mining the quartz is crushed and passed through the mercury stage of the placer-mining.

Gold is a yellow metal valuable for its lustre, softness and malleability. It can be beaten out into translucent sheets. It forms alloys with copper for coinage and jewelry. The standard of American gold coin is nine parts of gold to one of copper. The purity of gold is measured by carats; pure gold is 24 carats. Gold that contains 20 parts gold to 4 of copper is 20 carat gold. 18 carat gold contains 18 parts gold to 6 of copper. The number of carats represents the parts of gold out of 24. There are two chlorides of gold.

Auric Chloride	($Au\ Cl_3$)
Aurous Chloride	($Au\ Cl$)

RADIUM.— One of the most wonderful metals known to Chemistry was discovered in 1903 by Professor and Madame Curie of Paris. The metal is obtained from pitchblende found in Hungary and Colorado. The metal was named by Mme. Curie. Its most wonderful property

is what is called radio-activity. This is the power of producing rays whose activity is six times as energetic as the X-rays. These rays traverse the atmosphere, iron plates, and other dense media with the startling rapidity of 100,000 miles per second. The light is pale blue and is given off without any apparent diminution of energy. An intensely bright light is emitted by a particle so small as to be scarcely visible to the naked eye. The rays of light are called electrons. There is no heat accompanying the light and yet the rays have the power of burning without a sensation of heat. When the rays act upon human flesh the effect is similar to, but stronger than that of Roentgen or X-rays. It causes a decomposition similar to a burn but much harder to heal. Experiments have been made upon bacilli, cancers, and other forms; but great care must be exercised in its use, for a small particle enclosed in a sealed glass tube, killed plants and small animals in a short time. This power of radio-activity is shared by other metals such as polonium, actinium, and thorium. Chemists are unable to explain the phenomenon, the most puzzling part being the fact that there appears to be no loss of energy.

ORGANIC CHEMISTRY

This is the chemistry of the compounds of carbon. These may be divided into (1) Hydrocarbons, (2) Alcohols, (3) Aldehydes, (4) Acids, (5) Ethers, and (6) Ethereal Salts.

HYDROCARBONS

Carbon and hydrogen combine in a greater number of proportions than any other two elements. Their compounds are the hydrocarbons. There are nearly two hundred of these.

PETROLEUM AND ITS PRODUCTS

The first settlers who pushed across the Alleghany Mountains to make their homes in western Pennsylvania, and eastern Ohio noticed that a peculiar kind of oil flowed with the water from many of the springs of that region. This oil spread over the water in the brooks and creeks and made it glisten in the sunshine with all the colors of the rainbow. On some of the streams oil was present in considerable quantities, and one stream that emptied into the Alleghany River was

given the name of Oil Creek, because it bore on its surface such a heavy coating of oil. Years afterward, a town was built upon the banks of this stream and was called Oil City.

The oil of the springs was *petroleum*, a name meaning *rock oil.* It is a thick black substance, which looks a little like molasses. It smears whatever it touches, is easily set on fire, and smells of coal gas. At first, owing to its odor and the fact that it was supposed to have some relation to coal, it was called *coal oil.* Though petroleum is spoken of as an oil, it is in fact a compound of several oils and other substances. Not fewer than a dozen useful substances are derived from it, and of these we shall learn more presently.

Petroleum is found in beds of rock from 100 to 1,000 feet below the surface. The oil rock is usually a hardened bed of gravel or sand lying between two veins of shale, which is another name for slate or soapstone. The rock forms layers, varying in thickness from a few inches to 125 feet and the pores of the rock are full of petroleum. The slate rock above and below the oil-bearing rock will not allow the oil to pass through, and it is held fast in the pores of the rock, as if in a great bottle. In order to obtain the oil, wells are drilled through the layers of shale that lie about the oil and form the upper side of the bottle and the oil is taken out.

The machinery for sinking an oil well is quite simple, and was borrowed from the older practice of making salt wells. First, a strong wooden framework about 60 feet high is built. This framework is generally 20 feet square at the bottom and five feet square at the top, Heavy posts form the four corners, and there are side pieces every few feet, with braces across, to make the framework strong. This is called the derrick, and it is used for taking out and replacing the drill while the well is being made.

The floor of the derrick is made of planks, and in the center there is a hole 10 inches across. This is the top of the well. Some distance away is the engine shed containing a steam engine to furnish power for sinking the well and afterward for pumping up the oil. A long piece of wood reaches from the engine shed to the center of the derrick floor. This piece of wood is a heavy beam, thick in the middle and smaller at the ends. Near its middle this wooden beam is pierced by a round bar of iron, the ends of which project six inches on each side of the beam. The iron bar is supported upon a frame high enough to allow the beam to move up and down like a seesaw. One end of the beam is fastened to the engine crank, and as it turns the other end plays up and down over the top of the well. On account of its motion the beam is named a *walking beam*, and the whole apparatus around the well is called the *rig*.

The first step in sinking an oil well is to drive an iron pipe down through the ground to the rock, which is generally about 30 feet below the surface. The pipe is cut in short pieces called *sections*. One of these is placed in the hole in the center of the derrick floor under the walking beam. Upon the end of the beam has been placed a block of wood like a big mallet, and as the end of the beam moves up and down, this block strikes the pipe and drives it into the ground. When a section of pipe has been driven entirely into the ground, another is placed on top of it and the work proceeds. When the rock is reached the drilling begins.

The *drill* is made of steel in the form of a wedge, and the edge is made sharp so as to cut the stone. The drill is held in a heavy piece of iron called the *bit*. The bit and the drill together are about ten feet long, and are suspended in the well by a rope which passes through a pulley at the top of the derrick and over a reel in the engine shed called a *windlass*. The drill being let down to the rock by the rope, the latter is fastened to the walking beam. By this the drill is raised about 56 inches at each turn of the engine crank and allowed to fall upon the rock. The drill strikes the rock with a force equal to the combined weight of drill and bit. After each stroke the drill is turned slightly and the rope lengthened a little. In this way a hole is cut into the rock at the rate of several feet a day. Every hour, or so, it is necessary to lift out the bit, to replace the drill with another newly sharpened, and to clean out the sand in the hole. The sand is removed by a machine called the *sand pump*. It is a tube that has a valve, like a water pump, which sucks up the sand at the bottom of the hole. After the sand has been removed the drill is replaced and the work goes on as before.

The men engaged in drilling the well often know the depth at which they may expect to find the oil, and when it has been reached, they say they have "struck ile." After the well has been drilled and the oil has been found the *casing* of the well takes place.

This consists in putting in a pipe with tight joints, which extends to the bottom of the well. The bottom section of this pipe is pierced with small holes through which the oil enters the pipe.

There are two kinds of wells, known as flowing wells and dry wells. In the former the pressure of the oil or gases in the oil basin, or bottle, as we call it, is sufficient to force the oil up to the surface of the ground. The dry well, as it is called, yields oil only when it is pumped to the surface. Many of the wells fail after a time because the supply of oil becomes exhausted. It is then necessary to drill deeper or to abandon the well. The average duration of an oil well has been found to be about five years.

The sinking of wells to obtain petroleum began in 1859. In that year some of the oil from a spring near Titusville, Pa., was sent to Professor Silliman of Yale College, then the most eminent chemist in the United States. Professor Silliman's report upon the sample sent to him was favorable, and a company was formed in New Haven, who sent E. L. Drake to Pennsylvania to purchase lands and drill oil wells. The first well was drilled by him, and oil was found at a depth of 69 feet. Other wells were sunk soon afterward in the vicinity of the first one and in a short time petroleum became an important product.

One of the chief difficulties that had to be met by the men who developed the oil industry, was the transportation of the oil from the well to the refinery, where it was made ready for use. The refineries were in Boston, Pittsburg, and Philadelphia. The oil wells were many miles away, in the half-settled counties of western Pennsylvania. There were no railroads connecting the oil regions with these cities and hauling the oil out by horses and mules was slow work. The crude oil had to be shipped down Oil Creek in barrels on flat boats. As the passage could be made only when the water was high after heavy rains, this mode of carrying the oil down stream proved expensive and dangerous; but for a few years the oil was taken to the refineries at Pittsburg in this way. Finally a railroad was built to the wells; great tanks were built in which to store the oil, and it was carried away in barrels as it was wanted. Then the barrels were replaced by steel tanks placed on car wheels and forming oil cars. Finally, iron pipes were laid all the way from the wells to Pittsburg, New York, and other cities. These now carry the oil. There are 6,000 miles of these pipes now in the United States, and they convey every year many thousand barrels of oil from the wells to the places where it is refined.

Refining petroleum is separating the various substances it contains and making them fit for use. This is done by heating the petroleum in closed vessels provided with pipes to carry off the substances of which it is composed. The closed vessels are retorts. With the pipes they are called stills, and the separation of the petroleum into its constituents by heat is termed distilling it.

There are two kinds of distillation, known as distilling *in vacuo* and *cracking*. In the first, the petroleum is distilled in a partial vacuum, that is, the retort has nearly all the air pumped out and then the heat is applied. The second form of distillation is by means of heated steam. The name comes from the cracking sound, as the hot steam comes in contact with the cooler petroleum.

The various substances of which petroleum is composed may all be converted into vapor if sufficiently heated, but some are converted

into vapors at quite low temperatures, and others only at very high temperatures. Consequently, when heat is applied to the still and its temperature begins to rise, the various constituents are successively converted into vapors and driven off. By collecting in separate vessels those substances given off at different temperatures we obtain a number of very different products.

The first substance that comes from the retort after distillation begins is a clear liquid called *gasoline*. It is converted into vapor in the retort and is condensed by passing through the pipes of the still, which is cooled with cold water. Gasoline receives its name from its use in making burning gas in small gas machines. It is easily converted into a vapor and by passing air through gasoline a mixture of air and gasoline vapor is formed which burns readily and can be used for fuel or lighting.

The second product from the still is *naphtha*, a liquid closely resembling gasoline, but not so easily converted into a vapor. Consequently it is not so soon given off from the still.

There are three naphthas, called A, B, and C naphtha, which appear one after the other. C naphtha is sometimes called *benzine*.

Kerosene, or lamp oil, is the next substance separated from the petroleum. Kerosene means wax oil, and the name was applied because of its close relation to paraffin, a kind of wax which is the last substance obtained in refining petroleum. In Europe, kerosene is called paraffin oil, and in this country passes under certain grades known as water white, standard, and prime, names used principally by the manufacturers and dealers to indicate the purity of the oil.

Lubricating oils, of three grades, are next produced from the petroleum still. They are used for oiling machinery and for the manufacture of other lubricants.

The last product is paraffin, which has already been mentioned. The wax from which candles are made is paraffin. The name is derived from two words which mean without affinity, and was given to this substance because it resists the action of nearly all chemical agents.

Men are not yet agreed as to the origin of petroleum. Some of them think that it is formed by the distillation of vegetable and animal matter, by the heat beneath the surface of the earth. This view of the origin of petroleum is the one that is most generally held. A few chemists think that petroleum is formed by the action of water on certain heated minerals.

The simplest hydrocarbon contained in petroleum is marsh-gas, methane or fire-damp (CH_4). This substance is formed by the decaying vegetation in marshes and pools. Vegetable matter is com-

posed of carbon, hydrogen, and oxygen. When it decays in the air, it breaks up into carbon dioxide (CO_2) and water (H_2O). But when it decomposes under water and away from the air, marsh-gas (CH_4) is formed. If a pole is thrust down into a marshy pool, great bubbles of gas will be seen to rise. This is the marsh-gas. When it occurs in coal-mines, the miners call it fire-damp. When it is mixed with about eight times its volume of air it is very explosive, and is the great cause of explosions in coal-mines. It was to overcome this that Sir Humphrey Davy invented the special lamp known as the Davy safety-lamp, which is simply a light surrounded by fine meshed wire-gauze.

Chloroform ($CH\,Cl_3$).—A valuable anæsthetic, obtained by distilling a mixture of water, lime, chloride of lime (bleaching powder), and alcohol, when it passes over, along with water, and is caught in the receiver. It is next washed with water to remove the alcohol, and later with a solution of carbonate of potash; it is then dried with chloride of calcium and rectified. When rectified, it is a colorless, volatile liquid, with an agreeable, ethereal odor, a sweet but slightly acrid taste. It is a good solvent of resin, gutta-percha, iodine, bromine, and the alkaloids. By its effect upon the nervous system, when used as an anæsthetic, chloroform causes a suspension of voluntary motion and of sensation, while respiration and the action of the heart are continued. Care should be taken, however, in administering it.

Anæsthetics.—Substances which produce insensibility to pain, either total or local. They include such as: Chloroform, ether, nitrous oxide or laughing-gas, cocaine, thymol, aconite, belladonna, chloral, phenol, and Indian hemp. It is only within the nineteenth century that their use has been known. Since their introduction the science of surgery has made wonderful advances. Their discovery is probably one of the greatest boons to humanity.

Iodoform ($CH\,I_3$).—Is made from alcohol, an alkali, and iodine. It is solid and soluble in alcohol and ether, but not in water. It is much used as a dressing for wounds usually in the form of gauze.

Ethylene or Olefiant Gas (C_2H_4).—Is formed by heating alcohol and concentrated sulphuric acid. It is a colorless gas, combustible, and, mixed with oxygen, explosive.

Acetylene (C_2H_2).—A transparent, colorless gas with a pungent odor, formed when coal gas is imperfectly burned in air. Acetylene is readily obtained by treating dry calcium carbide with water, when the gas is copiously evolved. It is inflammable and burns with an intensely brilliant light, which makes it serviceable for lighting purposes.

ALCOHOLS

Methyl Alcohol, wood spirit, (CH_4O).—This is obtained by the destructive distillation of wood. It burns without yielding light or smoke, and is used in dissolving gums and resins in the manufacture of varnishes.

Ethyl Alcohol (C_2H_6O).

Alcohol.—(See Fermentation.) The active intoxicating principle of fermented liquors. It is a hydrate of a hydrocarbon radical, and comprises many bodies of different chemical composition. Ordinary wine alcohol is formed by the breaking up by fermentation of glucose (grape sugar). Absolute or anhydrous alcohol contains no water. It has a sp. gr. at 60° of 0.794. It boils at 173° F., the sp. gr. of its vapor is 1.6133. It has never been frozen. Faraday caused it to thicken at 166° F. below zero. This quality makes it useful for thermometers to measure low temperatures. Spirit of wine or rectified spirit has a sp. gr. of 0.838, is 54 to 58 overproof, and requires 54 to 58 per cent of water to bring it down to proof. Proof spirit, the standard of all mixtures of alcohol and water contains 57.27 per cent by volume and 49.50 per cent by weight of alcohol. A mixture which contains less than this is said to be underproof. When mixed with water, say in the proportion of two gallons of alcohol to one gallon of water, the volume of the resultant mixture is less than the combined volume of the two ingredients—that is, it does not measure three gallons of mixture. Methylated spirits is a mixture of alcohol of sp. gr. 0.830 with 10 per cent of common wood spirit.

Glycerin ($C_3H_8O_3$) is an alcohol which occurs in fats. It is obtained from fats by boiling them with caustic potash or by heating them with steam. It is a sweetish, thick, oily liquid. As it attracts water-vapor from the air it is used to keep surfaces of the skin moist.

ALDEHYDES

Acetic or ordinary aldehyde (C_2H_4O) is formed by oxidizing alcohol. It is a volatile liquid, with a peculiar, penetrating odor. When left to itself it changes into paraldehyde which is much used in medicine.

Chloral Hydrate.—A preparation of chloral used in medicine as a means of producing sleep. Chloral is united with water to form a crystalline hydrate, which has great narcotic properties. It is administered either internally or by subcutaneous injection in doses of about

20 grains. Treated with alkalies, choral splits into formic acid and chloroform, used so beneficently to produce anæsthesia in surgical operations or to alleviate pain. Chloral hydrate is a white crystalline substance; chloral itself is a colorless oily liquid, with a pungent odor and harsh taste. Its symbol is $CCl_3.CHO$. The drug should be used only in the hands of a skilled physician, as its excessive use produces paralysis and insanity.

ACIDS

Formic Acid ($C\,H_2\,O_2$) is found in nature in stinging-nettles, in some pines, and in the red ant. It is from the Latin name of the ant—formica—that it derives its name. When a drop of this colorless liquid falls upon the skin it produces painful blisters.

Acetic Acid ($C_2H_4O_2$) is the acid that is contained in vinegar. If alcoholic liquids are exposed to the air, there is gradually formed in them a microscopic organic growth, called the mother of vinegar. Acetic acid is also formed by the destructive distillation of wood, which gives it the additional names of pyroligneous acid, and wood-vinegar. It is clear and colorless with a strong odor resembling that of vinegar. It has a blistering effect upon the skin. It is in its dilute form the ordinary vinegar of commerce. It is used to make dyes in the printing of calico. With the metals it forms acetates. The chief of these is lead acetate, Pb $(C_2H_3O_2)_2$, or sugar of lead; copper acetate, Cu $(C_2H_3O_2)_2$, which is verdigris. Fatty acids are so named because many of them are derived from fats.

Butyric Acid ($C_4H_8O_2$) is obtained from butter by boiling it with caustic potash.

Palmitic Acid ($C_{16}H_{32}O_2$) is obtained from many fats but especially from palm-oil.

Stearic Acid ($C_{18}H_{36}O_2$) is obtained from stearin. With palmitic acid it makes "stearin candles."

For the uses of fats in soap-making, see Soap.

Oxalic Acid ($C_2H_2O_4$) takes its name from the oxalis or sorrel family of plants from which it was first made. It is more economically obtained by heating wood-shavings with caustic soda and potash. It is poisonous. It is used in the printing of calico, and to clean brass and copper.

Lactic Acid ($C_3H_6O_3$) takes its name from the Latin name for milk,—lac. It is a sugar ferment product.

Malic Acid ($C_4H_6O_5$) takes its name from Latin, malum, an apple; as it is abundant in the juice of apples, cherries, and other fruits.

Tartaric Acid ($C_4H_6O_6$) is found largely in fruits, grapes, berries, potatoes, cucumbers, etc. It is made from « cream of tartar » which is an acid potassium tartrate found in crystalline form in the casks in which wine has been stored.

Citric Acid ($C_6H_8O_7$) takes its name from Latin, citrus, a citron-tree; as it is abundant in citrons and lemons to the extent of about 6 per cent of the juice. It is very sour in taste and is used as a substitute for lemons in making acid drinks.

ETHERS

Ether ($C_4H_{10}O$) is the representative of the class. It is made by treating ordinary alcohol with sulphuric acid and then distilling. It boils at a very low temperature and is very inflammable. It is a useful anæsthetic. When alcohol is subjected to the action of an acid, the alcohol is neutralized, and the product is an ethereal salt. The neutralization of the acid by the alcohol is not performed so readily as a base would do it, hence the qualifying use of ethereal in speaking of these salts.

Ethyl nitrate ($C_2H_5NO_3$) is made by the action of nitric acid on ordinary alcohol. When an ethereal salt is boiled with caustic potash, the salt is decomposed and alcohol and an alkali salt are formed. If ethyl nitrate is boiled with caustic potash, alcohol and potassium nitrate are formed as: $C_2H_5NO_3+K\ O\ H=C_2H_5OH+K\ NO_3$. This process is known as saponification for it is the first step in soap-making.

Fats are ethereal salts which are produced by the action of glycerin, which takes the place of the alcohol, and one of the three acids, palmitic, stearic, and oleic acid, $C_{18}H_{34}O_2$. When palmitic acid is used with glycerin, a palmitate of glycerl is formed; when stearic acid is used, a stearate of glycerl is formed; and when oleic acid is used, an oleate of glyceryl.

Butter is a formation of ethereal salts of glycerin and several fatty acids, including butyric, stearic, and palmitic acids.

Oleomargerin is an artificial product made by using other fats than those contained in milk.

Ethereal salts are largely used in the manufacture of flavoring extracts and fruit essence. They are well adapted for this, because fruits owe their flavor to the presence of these. The artificial essence of pineapples is the ethyl salt of butyric acid; the essence of apples is the amyl salt of valeric acid.

Nitro-glycerin, a product of glycerin, has been treated elsewhere. It is to be classed as a derivative of the ethereal salts.

CARBOHYDRATES

Under this class are contained many of the most important substances in nature. A hydrocarbon contains carbon, hydrogen, and oxygen. A carbohydrate contains carbon, hydrogen, and oxygen, but the hydrogen and oxygen are always present in the proportions necessary to form water. Among the carbohydrates are: grape-sugar or glucose, cane-sugar, starch, cellulose, gum, and dextrin.

Glucose, Grape-sugar, Dextrose, $C_6H_{12}O_6$. Under this term are classed several distinct substances either directly or indirectly prepared from animal or vegetable products, such as dextrose, grape, and starch-sugars, syrups, etc. They are derived naturally from ripe grapes, honey, cane-sugar, etc., or from starch, by the action of heat and acids. Glucose is now largely manufactured in the United States, where it is used in the manufacture of table-syrups and confectionery, in the brewing of ale and beer, and in the preparation of a food for bees and of artificial honey. The glucose of commerce is thick and tenacious, of a slightly yellowish tint, though nearly colorless, and with a specific gravity, at 20°C. or 68° Fahr. of 1.412. Its sweetness varies with different specimens: that derived from cane-sugar is the sweeter.

Dextrose is largely made from corn-starch in America, and from potato-starch in Germany, by boiling with sulphuric acid.

Grape-sugar is the name given to the dried or solidified dextrose and glucose. These products are not nearly so sweet as the products from cane-sugar. The proportion of sugar is about three to five. Cane-sugar, $C_2H_{22}O_{11}$.

A vegetable product of great commercial importance. It is mentioned as having been found in India, 325 B. C. Sugar-cane was first introduced into the United States in 1722, being cultivated by the Jesuits in Louisiana. The first sugar mill was built in 1758, near New Orleans. Sugar is made principally from the sugar-cane, but there is now a very extensive beet-sugar industry in many European countries, and a limited production in the United States.

Sorghum.—A Chinese sugar-cane, introduced into the United States about 1854. It is cultivated extensively in the Southern States and its product is syrup.

In the refining of sugar, the sugar-cane is macerated or broken up with water to dissolve out the sugar. The dark-colored solution thus obtained is evaporated, and filtered through layers of bone-black or animal charcoal, which takes the color out of it to some extent. The liquid is then evaporated in "vacuum-pans," which are vessels

from which the air has been partially exhausted. This allows the liquid to boil at a much lower temperature than would be the case in the open air, and not only saves fuel, labor, and time, but prevents the possibility of burning. The resulting product is composed of crystals of sugar mixed with mother-liquids. To separate these, the product is placed in rapidly revolving funnel-shaped sieves. The liquid is thrown off by centrifugal force and the crystals remain in the sieves.

Molasses. — The mother-liquids, which are thrown off in the refining, are then taken, and evaporated. The first products of repeated evaporations are lower grades of sugar, and the final product is molasses.

Caramel is crystallized sugar heated to 210° or 220° and thus converted into the brown substance known by this name.

Dextrose and Levulose. When cane-sugar is treated with dilute acids, it breaks up into dextrose and levulose. These are the substances which produce fermentation. Cane-sugar does not ferment.

FERMENTATION AND ITS PRODUCTS

Fermentation is mentioned in connection with the action of yeast in "bread-making." It is, however, a process of too great importance to be passed by with a mere mention, and herein it will be described more fully, and an account given of some of the industries in which it plays a leading part.

The name *Fermentation* is applied to changes brought about in a number of substances, of which sugar is the chief, by the action of certain chemical compounds that have the power of bringing about chemical changes, without being altered themselves. The living organisms that bring about fermentation are plants which are so small that they are visible only through a microscope; these are variously known as *germs*, *microbes*, *bacteria*, *ferments*, etc.

The chemical compounds that have a similar action are known as unorganized ferments, or *enzyms*. The action of the *enzyms* usually takes place within the substance of plants during the processes of growth, and, therefore, has but little direct bearing upon human industries. The fermentations that are of most importance are brought about by living plants, the most common varieties being the alcoholic, acetic, and lactic fermentations.

Alcoholic fermentation, the most important of the three varieties, is that which is brought about when the yeast plant is introduced into a liquid containing starch or grape-sugar. The products of this chemical action are alcohol and carbonic acid gas.

Lactic fermentation is that which causes the formation of lactic acid, from the sugar contained in milk. Acetic, or acetous, fermentation is due to the vinegar plant, which acts upon alcohol and transforms it into acetic acid. The manufacture of vinegar depends upon this action.

Alcoholic fermentation takes place in a number of natural processes, such as in bread-making, and in the manufacture of wine and beer. It is in the making of the two last named, that alcohol fermentation finds its most valuable commercial application, and the manufacture of those beverages will now be described.

The term wine has been applied to the fermented juice of a large number of different fruits, such as currants, blackberries, oranges, gooseberries, cocoanuts, etc., but ordinarily it means the liquid obtained by the fermentation of grape juice. In the manufacture of wine from grapes, the bunches of ripe grapes are cut from the vines, cleaned, and then put into the wine press, in which they are crushed to squeeze out the juice. The presses are sometimes nothing more than large tubs having holes for the juice to drain through, and the mashing is accomplished by men treading the grapes with their bare feet. Mechanical presses, however, are more frequently used.

The juice pressed from the grapes, which is called *must*, is put into vats or barrels and set aside to ferment. It is not necessary to add any yeast to cause fermentation, for yeast germs are present in the air, and there are present in the grape juice all the substances necessary to their growth.

By the fermentation the sugar in the grape juice is partially or wholly changed into alcohol. When there is much sugar present only part of it is changed, and the resulting wine is sweet. If the grape contains but little sugar, it is all changed to alcohol, and a *dry* wine is produced.

The wine may be bottled before the fermentation process is complete, or it may be allowed to remain in the vats until fermentation stops. Wines that are bottled before fermentation ceases always contain some carbonic acid gas, which escapes when the wine is poured from the bottles. These are called *sparkling* wines, in contradistinction to those bottled after fermentation is complete, which are known as *still wines*. Champagne is an excellent example of a sparkling wine.

Beer is an alcoholic beverage made from some grain, usually barley. The first step in its manufacture is to steep the barley in water and keep it warm until it sprouts. It is then dried in kilns to check the growth that has begun, and the substance obtained is called malt. The malt is crushed, and is then placed in vats partly filled with water, and kept in a temperature of from 120° to 170° F. This treat-

ment is called *mashing*, and it is done to permit the conversion of the starch and dextrin of the grain into sugar through the agency of a substance called *diastase*, which is formed in the grains when they sprout. Diastase is one of the organized ferments or enzyms, which have already been mentioned.

The liquor obtained by the mashing is called *wort*, and it contains a large proportion of sugar. If it were fermented, however, the liquor resulting would have a very disagreeable flavor. To avoid this, hops are added to the wort, and the mixture is then boiled. After the boiling, the wort is cooled rapidly to prevent the formation of lactic acid, which is apt to occur when the cooling process is slow.

The wort is now ready for the last stage in the manufacture of beer — the fermentation. This, like that in wine, might take place by the aid of the air, but the process is more successful when yeast is added. When the fermentation is complete, the beer may be run into casks without further treatment, but it is generally filtered after it has ceased fermenting.

Invert-sugar is the name given to a mixture of dextrose and levulose. The names dextrose and levulose are derived from the Latin words for the right hand, dexter; and the left hand, lævus. They refer to their action under the saccharimeter. This is an instrument used for testing the strength of sugar by means of the rotation of the plane of a ray of polarized light; dextrose causes it to revolve to the right and levulose to the left. The size of the angle of rotation on a graduated circular disk is the degree of sweetness of the solution or the indication of its strength.

Lactose, or sugar of milk ($C_{12}H_{22}O_{11}+H_2O$), occurs in the milk of all animals. The milk-sugar of commerce is obtained in cheese-making. Cow's milk is composed of:

Water	87	per cent
Casein	4.75	per cent
Butter	4	per cent
Mineral Matter	3.5	per cent
Sugar of Milk	.75	per cent
	100.	

Human milk is composed of:

Water	88.02	per cent
Sugar of Milk	7.03	per cent
Butter	2.9	per cent
Casein	1.6	per cent
Mineral Matter	.45	per cent
	100.	

By adding rennet to milk the casein is separated and the cheese is formed; the sugar of milk remains in the liquid and is obtained by evaporation. When milk sours, it is due to fermentation which changes the milk into lactic acid. The milk becomes thick because the lactic acid coagulates the casein.

Cellulose, $C_6H_{10}O_5$, is the hard structure, or skeleton, or woody fiber of all vegetable growth. Wood is nearly all cellulose as are also cotton, hemp, and flax. It is not soluble except in concentrated sulphuric acid. If this solution is diluted and boiled it breaks up into dextrose and levulose. As rags, paper, wood, old rope, etc., are mostly cellulose, it may be seen that both sugar and alcohol can be made from these substances.

Gun-cotton, pyroxylin, and nitro-glycerin, have already been referred to. Collodion is a solution of gun-cotton in mixed ether and alcohol. It is much used in photography as the ether and alcohol will evaporate from the surface of glass upon which it is poured and leave a layer of gun-cotton upon the plate. This is one step in plate-making.

Celluloid is a mixture of gun-cotton and camphor. It can be softened and molded at comparatively low temperature. From its composition it will be seen that it is highly inflammable and dangerous when brought near to heat. Many painful and distressing accidents have occurred from carelessness in this matter.

PAPER-MAKING

The earliest form of paper was that made by the Egyptians from the *papyrus* plant, from the name of which the word paper is derived. This plant is a species of reed and in the ancient method of paper making its stalks were cut into as thin slices as possible, and placed side by side. Another layer was arranged in a similar manner across the first, and the whole was placed under a press, where it dried into a single sheet. When this was rubbed smooth it formed a kind of paper, that could be used for writing.

The paper of the present time consists of thin sheets, that are composed of vegetable fibers closely felted together. One of the first materials used for making it was cotton, from which paper is said to have been made as early as the 11th century.

Vegetable fibers are all composed of a substance called *cellulose*, together with certain other substances which surround, or incrust, the cellulose, and hold the short fibers in which it occurs.

The fibers that seem naturally best adapted for the manufacture of paper are those of cotton and flax, and in a time when the uses of paper were comparatively few, a sufficient quantity of paper-making material was found in the old cotton and linen rags that are always accumulating in every household.

In the manufacture of paper from rags, by the old process, the rags were caused to putrefy for a few days, to remove the substances that incrust the cellulose, and they were then beaten into a pulp, to which a large quantity of water was added. The pulp was thrown into a sieve, in which it was shaken to and fro by the workmen, until the greater part of the water had been drained off, and the cellulose fibers formed a thin felted layer, on the bottom of the sieve. This layer was then piled up with other similar layers, and the whole pile was placed under a press, where more of the water was removed. The layers, or sheets, were taken from the press and dried.

Paper made in this way was loose in texture and very absorbent, like blotting paper. To give it durability and a fit surface on which to write, it was necessary to *size* it. This operation, which filled the pores and gave the paper great firmness, was accomplished by drawing the sheets through a solution of alum and glue, or some similar substances, and then drying them. The paper was then passed between highly polished rollers, to glaze it, or, if so smooth a surface was not desired, it was simply pressed between flat surfaces while moist.

In the modern method of manufacturing paper by machinery, the rags are boiled with caustic soda, to separate the cellulose fibers, and are then placed in a breaker in which rollers set with knives tear the rags to pieces and mix them with water to form a pulp. The pulp is then bleached with chloride of lime, and is passed on to the sizing machine. This machine mixes the pulp with alum and with a kind of soap, made from suitable resins which serves the purpose better than glue.

The pulp which is now ready to be made into paper, is poured out upon an endless cloth made of fine brass wire. This cloth travels constantly in one direction, by means of rollers, and is given at the same time a sort of vibratory motion, to cause the paper fibers to become more closely felted together. On the wire cloth web are usually woven words or designs, in wire, that rise above the rest of the surface. These are transferred to the paper, and are called water-marks. The machine then winds the finished paper into rolls, so that it may be handled conveniently.

In the past fifty years, the uses for paper pulp have been so great that the supply of rags has been by no means sufficient to meet the

demand for material, and, consequently, much effort has been expended in the production of pulp from other materials. Since all vegetable fibers contain cellulose it would naturally be supposed, that the production of pulp from other materials than rags, would be a simple matter; but a satisfactory substitute that could be prepared at low cost was not found at once. Straw and esparto grass, a plant that grows wild in North America, were found to yield cellulose having the desired qualities, but it was desirable to find some method of converting wood into a pulp suitable for paper-making, and many attempts were made before success was obtained. At first the powder formed by grinding up logs was used, but the paper produced was not strong, and could be used for very few purposes.

Finally, however, it was discovered that if wood shavings were boiled in strong solutions of caustic soda, contained in boilers that would stand very high pressure, the shavings were separated, and a very good quality of cellulose for paper manufacture produced. As it comes from the boiler, however, the *soda cellulose*, as that produced in this way is called, is of a dark color, and must be bleached before it is fit for use in paper-making.

Of late years the sulphite process for preparing cellulose has almost superseded the soda process. In the former, a solution of the acid sulphite of lime is used instead of caustic acid. Acid sulphite of lime is formed when the fumes from burning sulphur are passed through chimneys filled with lime. This substance does not only disintegrate the wood shavings, but at the same time bleaches the cellulose, making it considerably whiter than that obtained by the soda process.

A difficulty that accompanies the use of acid sulphite of lime in making cellulose was the making of boilers in which the operation could be carried on. The boilers used in the soda process could not be employed with the sulphite, because iron is dissolved by the acid sulphite, and lead, which is not dissolved by it, is too soft to stand the pressure required. The difficulty was finally solved by lining iron boilers with flag stones joined together by a proper kind of cement.

The sulphite cellulose is now, not only driving out of the market all other materials for making paper, but attempts are being made to disintegrate the wood in such a way, that it may yield cellulose in fibers long enough to be woven with cotton.

The cheap methods of producing cellulose have led to the use of paper and paper pulp for many purposes for which it would otherwise never have been employed. In many cases the paper is used in the form of *papier mâché*, a tough, plastic substance, which is made

by mixing glue with paper pulp, or by pressing together a number of layers of paper having glue between. *Papier Mâché* can easily be molded into any desired form, and after drying it forms a very tough substance and one that will stand rough usage. It has been employed for making dishes and utensils of many other kinds, for making the matrices for electrotype plates, for car wheels, and it has recently been molded into boards that were used in building houses.

STARCH

$C_6H_{10}O_5$, occurs abundantly throughout the vegetable kingdom. It is made from maize and potatoes. The potatoes or maize, are mashed, or ground, in running water, which carries off a thin paste. This is passed into moving strainers of silk-cloth. The liquid passes through to a tank where the starch settles. The water is drawn off. The starch is then treated with an alkali which dissolves out the oil, gluten, and other impurities. The alkaline water is run off and the pure starch is washed with clear water and slowly dried. On drying it cracks and breaks up naturally into the odd-shaped pieces in which it is seen. It is not soluble in cold water to a great extent, but more so in boiling water with which it forms a starch paste.

FLOUR

Bread-making is an art that has been known and practised by mankind so long, that we have no record when it was begun. In the Bible, bread is mentioned as the food of people who lived and died more than three thousand years ago; and bread, very much like some we see nowadays, was recently found in the ruins of Pompeii, where it had lain nearly two thousand years.

Notwithstanding its age, bread-making is still a very important art, for bread is to-day, probably, the chief article of food to the human race. It is well worth our while to trace the steps by which the grain is converted into loaves of bread.

First we must pay some attention to the grain itself, the wheat that furnishes the flour of which the bread is made. An account of this cereal is given in our article on Wheat.

No doubt you know, that the very first step in bread-making, is to mix water or milk with flour. If we added nothing else, however, and then baked the dough, we should have a kind of bread that is very solid and firm, and on that account is much used by soldiers,

who have to carry their food with them in knapsacks. Perhaps you have seen such bread, and know how hard and solid it is. On account of its hardness it is called "hardtack," and if you have ever eaten any you know that the name is a good one. To most people such hard bread is not pleasing, so we add a little yeast, or baking powder, to our mixture. We shall have occasion to refer again to the subjects of yeast and baking powder, and just now we need only say that they cause fermentation to take place in the dough.

When the bread is first mixed it is sometimes left in the form of a batter, which, when the yeast has been added, is called the *sponge*. After fermentation this becomes very spongy indeed. More flour is then added, and the mixture is kneaded or "worked" into a smooth, elastic mass called *dough*. Another method, is to add sufficient flour at the first mixing to form a dough. In either case, the dough is left in a warm place, and the fermentation soon begins.

As a result of the fermentation, small bubbles of carbonic acid gas are formed in the dough, which begins to rise because the bubbles of gas that form all through it force it upward. If the dough be now put into a hot oven, the fermentation is increased for a time; the heat causes the small bubbles of gas to swell, and the dough rises rapidly; but when it has become nearly as hot as boiling water the fermentation is suddenly stopped, and further baking keeps the mass in its expanded form.

When the baked bread is cut, it is found to be full of small holes, formed by the carbonic acid gas that was produced in the fermentation. The whole loaf is light and spongy, instead of being hard and solid, like the hardtack made without yeast. The yeast, therefore, plays a very important part in bread-making, and its action is worth still further study.

Its first effect is produced upon the starch granules, some of which it changes to sugar, and the sugar in its turn is changed into alcohol and carbonic acid gas. As the gas cannot escape from the dough, it causes it to swell, and on being heated the bubbles expand and make the bread still lighter. Meanwhile the starch on the outside of the loaf, which heats more rapidly than that on the inside, has been converted into a pasty substance called *dextrin*, which hardens and forms the crust. As the heat becomes greater on the inside of the loaf, the yeast is "killed," as we say, and the fermentation is stopped; most of the alcohol evaporates, leaving only two parts of alcohol in a thousand parts of bread; the unfermented starch granules burst, and the cooking is complete.

Bread formed in this way is more suitable for food than the grain in its natural state would be. It has three distinct advantages—

first, it is more palatable; second, it is easier to chew and to mix thoroughly with the fluids in the body that must do the work of digestion; third, the grains of starch have swollen and burst, and may be readily converted into sugar in the body, while in the raw state they cannot be acted upon so easily.

Bread made with yeast is open to two criticisms. In the first place, it takes an hour or more for the yeast to produce the necessary fermentation before the dough can be put into the oven; and, in the second, the bread loses some of its value as food in the fermentation process. As we have seen, some of the starch is converted into alcohol and carbonic acid gas; the greater part of the alcohol escapes, and the gas has no nourishing effect. On account of these objections to the method of making bread with yeast, various substances have been used to produce the carbonic acid gas in the dough without destroying any of the starch by fermentation.

These agents are known as baking powders, and, when mixed with the dough and put into a hot oven, they decompose and give off carbonic acid gas in the dough in little bubbles, like those produced in yeast fermentation. Baking powders act more quickly than the yeast, and do not cause any of the starch of the flour to be destroyed; but some of them leave injurious substances in the bread, some are uncertain in their action, and many are expensive.

There is another method of making bread light that has been used only a few years, which seems free from these objections, but its use is practicable only in baking houses, where many loaves are made at one time. In this method no yeast or baking powder is required. The dough is made light by forcing carbonic acid gas into it by machinery, and there is no waste of starch by fermentation, nor is there any objectionable substance left in the bread.

A cheap substitute for the baking powders that are sold ready for use is the mixture of bicarbonate of soda (baking soda) and sour milk, which is so much used in some parts of the country. The effect of this mixture in "raising" the dough is brought about by the action of the lactic acid, always present in sour milk, upon the soda. The acid and the sodium present combine to form *sodium lactate*, and the carbonic acid gas is set free.

Though yeast and baking powder were unknown to the Ancients, they had learned that when flour and water were mixed and allowed to stand for some time, fermentation took place, and a gas was formed. They also knew that when a lump of dough, in which fermentation was going on, was mixed with fresh dough, the whole mass was made to ferment. This knowledge enabled them to make light bread, for it was easy to keep a small quantity of flour and water fermenting,

and to mix some of it with more flour and water to make bread. Bread made in this way is known as *leavened* bread, from the fermenting dough called *leaven*. Bread made without leaven is unleavened bread, which is referred to so often in the Bible; it contains nothing to make it light, and is much like hardtack.

The *salt-rising* bread, that is made in the northern and western parts of the United States, is a kind of leavened bread, the leaven of which contains salt. The term *salt-rising* is misleading, for the salt has nothing to do with the rising of the dough.

Crackers and wafers are made in various ways, but they never contain yeast or leaven, and very seldom contain any soda or baking powder. Their flaky structure is due chiefly to the greater amount of kneading that is given the dough.

COAL-TAR PRODUCTS

When coal is destructively distilled in making illuminating gas some of the by-products are: benzene, C_6H_6; toluene, C_7H_8; xylene, C_8H_{10}; napthalene, $C_{10}H_8$, and anthracene, $C_{14}H_{10}$. These carbon compounds, derived from this ill-smelling material called coal-tar are the source of many aromatic substances.

Nitrobenzene, $C_6H_5\ NO_2$, is obtained by treating benzene with nitric acid. It is the artificial oil of bitter almonds.

Aniline ($C_6H_5NH_2$).—A substance originally obtained from indigo, but now derived from coal-tar, the refuse of gas-making. It is an oily colorless fluid, yet it is the base of the numerous aniline dyes numbering some hundreds. To produce them, the aniline is treated with an acid, which forms a base. These bases are in many cases colorless and develop tints only when converted into salts.

Carbolic Acid or Phenol (C_6H_5OH).—One of the important substances derived from coal-tar. Though termed an acid, and forming salts, it is neutral to test-paper, and has more in common with the alcohols than with the acids. It possesses a peculiar, penetrating, and characteristic odor, and is soluble in twenty times its weight of cold water, and in all proportions in alcohol, ether, and glacial acetic acid. It blanches and corrodes the skin and other tissues, without causing the sensation of pain, and hence is employed in dentistry to destroy an exposed nerve. Known as phenols, the chemical compound is employed largely as a disinfectant and antiseptic, as well as a source of various coloring matters.

Phenol, Carbolic Acid, C_6H_6O.

Other compounds of carbon derived from other sources are:

Benzoic Acid, $C_7H_6O_2$, occurs in gun benzoin, balsams of Peru and Tolu. But it is also made from coal-tar by oxidizing toluene.

Balsam of Peru, balsam of Tolu, and benzoin, are obtained from the thick, fragrant fluids which exude as gums and balsams from some trees of South America. Myrrh and frankincense are similar substances used in the form of incense.

Gallic Acid, $C_7H_6O_5$, is formed in tea, sumac, etc. It is an astringent or puckering substance, allied to tannic acid, and is much used in medicine.

Tannic Acid, $C_{14}H_{10}O_3$, occurs largely in the barks of trees, and in gall-nuts. These latter are round excrescences which grow on oaks and other trees. They are formed by the gall-fly which punctures the bark to find a place to lay its eggs. The portion of the bark swells into the rounded gall-nut. The solution of tannic acid gives a blue-black solution with iron-salts which form ordinary writing ink. Tannin is also used in making dyes and in tanning hides.

LEATHER AND TANNING

When skins are first removed from the bodies of animals they are but little adapted for use in any way. If kept moist, they soon rot. If they are dried, they lose their tendency to putrefaction, but become so hard and stiff that no use can be made of them. The various processes by which skins are rendered tough and pliable, and by which their tendency to putrefaction is removed, are known as tanning, and the product resulting from them is called leather.

The first thing to be done with skins that are to be converted into leather is to remove the hair from them. This is done by sweating, a process in which the skin is kept moist until enough putrefaction has taken place to soften it, and to loosen the hair, so that it may be easily scraped off. This is done either by hand or with a skiving blade, according to the quality of the hide. A quicker method of accomplishing the same result, however, is to soak the skins in milk or lime, or in a solution of sulphide of soda.

After the hair has been removed, the hides are steeped in a bath containing a little acid. This process serves two purposes: it removes any lime or sulphide of soda that still adheres to the skins, and, at the same time, causes the latter to swell, thus preparing them to absorb the tanning materials.

Tanning substances, or tannins, which are agents used in converting hides into leather, are found in a great many plants. Both tea and coffee, for example, contain them; but those that are used for

making leather are obtained from much cheaper materials. The barks of trees, especially those of the white oak, hemlock, and walnut, are most frequently used. The leaves, berries, and the young shoots of a variety of sumac, are also much used, as are several other substances that are less abundant.

In tanning with bark, the swollen hides and the tanning materials are laid in pits, in alternate layers, until the pits are full. Enough water to cover the contents is then added, and the tanning substances are gradually extracted from the bark and absorbed by the hides. As thick hides require large quantities of tanning material, the pits must be frequently emptied, and the hides covered with fresh bark. Tanning by this process necessarily requires much time; but the leather produced by it is correspondingly good. The greater length of time required for bark-tanning has always been objectionable, and many efforts have been made to devise means for shortening it. These efforts have been successful, and it is now possible, by the use of certain patented processes, to make heavy sole leather in thirty-six hours. This is achieved by means of tanning extracts, which are prepared by treating the tanning materials with water, and concentrating the resulting liquid.

Tanning with bark, or tanning extracts, is the method used for making thick heavy leather, such as sole leather; but for making the soft flexible leathers used in the manufacture of gloves, other methods are generally employed. Of these, alum tanning, or white tanning, and the oil process, are in most extensive use.

When hides are treated with a solution of alum and common salt, the alum penetrates the hides, and by being deposited between the fibers, prevents the hardening of the substances that cause the stiffness in untanned hides. When the product obtained in this way is rubbed thoroughly with fat, and the fat is worked in, an exceedingly tough and pliable kind of leather is produced.

The application of this method of tanning to the skins of such animals as lambs, kids, and dogs, produces leather of the kind used for gloves. By applying the same process to heavier hides, leather suitable for harness is produced.

The tanning of skins with the hair on, to be used as furs, is generally carried on by the aid of alum. The skins are first thoroughly cleansed with soap, then dried; after drying, they are covered on the inner sides with fat, which is rubbed in as thoroughly as possible. The skins are soaked for twenty-four hours in a weak acid bath, to make them swell a little, and they are finally tanned by a process of steeping in a solution of alum and common salt.

The last method of tanning that remains to be considered is that of oil tanning. In this method, the skins are freed from hair, and are swollen as for alum, and bark tanning. They are then rubbed with fat in the form of fish or whale oil. After being rubbed for a time, the skins are beaten in what is called a fulling machine, and are again rubbed with oil until they can no longer absorb it. It is sometimes necessary to repeat the rubbing and the pounding in the fulling machine, several times, in order to make the skins take up enough oil. The absorption process is accompanied by a chemical change causing a peculiar odor, that indicates the completion of the operation. The skins are then piled up in heaps and left for a considerable time. When sufficient oil has combined with the skins, they become yellow in color, which indicates that they have been converted into leather. When this stage is reached, the skins are washed in a solution of potash, which removes the surplus fat: they are then ready for the final treatment that prepares them for the use of the shoe and the glove manufacturers.

Before the tanning process, each hide was split from shoulder to tail into two sides. Each side is about half an inch in thickness, and this, of course, is too heavy to use in the manufacture of even the heaviest shoes. So the hides must be split. They are first trimmed of all roughness and are then put through a splitting machine whose keen knife slices through the tough leather as if it was so much paper, reducing it to the desired thickness.

After splitting, the side is dampened. So also are the splits, or the parts which have been taken off. The latter are placed in a large round revolving mill constructed with stakes inside. Some tan liquor is spilled over them and afterward they are sent to the stuffing-loft to be stretched to their utmost and stuffed, which means, covered with grease. They are then hung upon sticks near the ceiling and are dried by steam. When dry, they are taken down and the grease is scraped off by a slicker. Whiteners with sharp slickers, or by machines, trim the leather on one side, and sometimes on both sides, until the surface is smooth. The edges are trimmed, and in another department the "finish" is applied. The side most whitened receives a coat of soap-blacking, and is jacked by a machine, the roller of which touches every part of the blackened side. Light paste is spread over the blackened part and, in some cases, red or yellow paste is put on the other side. After pasting, and jacking, comes the gumming. This is done with sponges. In a few hours the splits are dried and are taken down from the sticks, sorted according to their weight and general excellence, and are weighed and baled. The small pieces taken off in the splitting are called slabs. Massachusetts exports

great quantities of split leather to Europe, and much more is used in America for a cheap grade of durable shoes.

Going back to the side of leather, we find it has been dampened and sorted. The shop skiving machine takes off some extra portions from the flesh side. The miller receives it, and if polish leather is to be made allows it to become well-soaked with oils; if it is intended for butt leather it is softened with grease. From the miller, the leather goes to the setters or stuffers, who are not the same as split-stuffers although they stretch the leather in much the same way. Setting machines are used where fine work is not especially needed. During the past twenty-five years, machines have so taken the place of hand labor that the trade of tanning is regarded with little of the favor of former years. Wages have greatly decreased, principally on account of the introduction of machinery.

After being set, the side that is to be polished is taken to the stuffers, who, with sharp slickers, take off nearly all of the red skin on the grain side. Blacking is then put on this side; there follows a rolling, and then a strong grain is indented in the blackened side. The machine doing this is called the pebbler. Such a machine can be fitted with rolls, the exteriors of which are cut so as to bring out on the leather over which it passes any sort of pattern desired. An oiling of this grain or pebble follows, and then the grainers receive the side and, by rolling a soft board made of cork over its surface, render it flexible, and fix the grain more firmly. If, on reaching the grainers, the side is not soft enough for graining, another man using the same kind of soft board makes it more pliable. The blackened and grained side receives two or more coatings of polish, and when dry the leather is ready for the measuring machine and the sorter. Polish leather and about all "grains" are sold by the foot. For instance, 1,000 sides of polish leather might measure 30,000 square feet; they would all have to be large sides. Splits, like calfskins, are sold by the pound. Polish leather is made largely into shoes and trimmings of various kinds. Satin-oil leather is made from a heavier side and has no grain but its natural one. It is treated mainly with oil, after blackening, and makes splendid material for water-proof shoes. Glove leather receives no graining, but is finished, after blackening, by a rolling which makes its surface compact, followed by a pasting on the blackened side, and then by the application of a soft creamy solution known as finish, which is spread over it with sponges. Buff leather receives no graining, but takes much grease in the stuffing. Other kinds are taking its place.

Nearly all of the imitation effects in leather made from cowhide are the product of the pebbling machine. These imitation leathers prove

even more acceptable, in some instances, than the genuine article. For instance, imitation alligator skin can be made with the help of the pebbler and can be used in the manufacture of articles for which the real alligator would be unsuited. The currying of modern leathers requires much good judgment. The great demand in recent years for red and russet-colored shoes caused many leather makers to turn their attention largely from polish leather to the manufacture of the new kinds. A plant getting out polish leather was in some respects fitted for making red or russet leather. There were many curriers able to select the sides at a glance, and to tell just how much splitting was necessary to reduce them to the desired weight for the new shoe-leather. But coloring experts for leather were few in this country. It was not long, however, before such work became well understood. Red leather receives little or no grease, but is stretched or set like polish leather. It is made from sides of grain leather—a term applied to every side of leather not a "split."

In making patent leather there is much fine splitting, and the side is left little thicker than heavy paper. Naturally there are several splits and slabs taken from such a side. After being set out on frames, the patent and enameled leathers receive a lustrous coating on the grain sides, the mixture being spread several times. Drying is done by the sun and by steam. Glazing machines are used on the enamel leathers, which are generally made from sides split heavier than the patent leathers. Most enamel leather is no more warrantable than patent leather, because of the lack of grease used in its manufacture. The light side would not hold grease, or, if it did, could not be treated successfully to the lustrous solution finish. The patent leather worker looks askance at patents, enamels, and similar leathers, knowing that they are likely to crack at any moment of wear. Generally he wears a sensible black calf or russet leather shoe. Such leathers as cordovan and morocco are made from light skins of small animals, and their surfaces are treated in much the same manner as are the sides of large leather.

A substance that is somewhat related to leather is parchment. Parchment is made from the skins of lambs or kids. The hair is removed from these skins, and they are cleansed carefully and dried while tightly stretched. A smooth surface is produced by sprinkling the parchment with chalk and rubbing it with pumice stone. In the Middle Ages, parchment was very much used to write upon, but it is now used only for certain forms of documents, such as diplomas and patents.

Indigo is a dye obtained from plants in South America, East and West Indies, Egypt. It is made from the substance indican which they contain. It is manufactured on a large scale artificially also.

NAPHTHALENE, $C_{10}H_8$, is a coal-tar product. It is a white crystalline substance suited for dyes and for the so-called "moth-balls," for protecting woolens from the moth.

ALIZARINE, $C_{14}H_8O_4$, is the "Turkey-red" dye of the root of the madder. The dye is now made from anthracene, $C_{14}H_{10}$, a coal-tar product.

ALKALOIDS

THESE are substances derived from plants. They are active medicinal agents. They contain nitrogen and are very like ammonia in their behavior.

QUININE is an alkaloid found in the bark of trees which grow in Peru. It is obtained from the Peruvian bark. Its use is medicinal as an antiperiodic in intermittent fevers, etc.

COCAINE.—A powerful drug, derived from the leaves of a South American shrub (*Erythroxylon coca*), and used to a large extent as a local anæsthetic. When used internally in moderate doses (¼ of a grain is a dose), it acts as a stimulant to the brain and to the spinal cord. It is of value also in minor surgery and in diseases of the eye and ear. Its use in excess is disastrous, in bringing on convulsions, and often is fatal. The properties and effects of cocaine, or coca, therefore resemble opium, though less narcotic, while it possesses the property, unlike opium, of dilating the pupil of the eye, and of lessening, in the user of it, the desire for ordinary food.

NICOTINE is the alkaloid of the tobacco plant. It occurs with malic acid.

MORPHINE is the alkaloid obtained from opium. Opium is a gummy exudation from the unripe seed capsules of a species of poppy grown in India.

STRYCHNINE is an alkaloid from the seeds of a species of plants found in Java. Nux vomica is also derived from these seeds and contain strychnia.

CAFFEINE OR THEINE ($C_8H_{10}N_4O_2$).—The alkaloid or active principle of coffee and tea. It is a white, bitter substance, and when isolated it forms beautiful crystals, which are soluble in water, alcohol, and ether. Medically, it is used as a powerful stimulant of the heart's action, but care should be exercised in its use, as 6 or 8 grains are sufficient to produce delirium. It has strong diuretic properties, and is also used in cases of deficient circulation and uneasy respiration. In single grain doses it gives relief in sick headache. Caffeine forms a series of salts, of which the citrate has come largely into use.

CHEMISTRY APPLIED TO THE USEFUL ARTS

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THE early history of chemistry reads like an Oriental tale. With rude implements and impure reagents great results were obtained and honors and distinctions won. An apothecary's clerk became the great Scheele; a medical student was made Baron Berzelius; the boy who walked to Paris developed into the mighty Dumas, famous as lecturer and cabinet minister; while Hoffman, once a poor student in Liebig's laboratory, discovered the aniline colors, and was called to fill the most important scientific office in the German empire.

Many great industries are dependent upon the knowledge of the chemist. The demand for trained chemists is greater than the supply, and is likely to remain so, owing to the rapid increase and extension of American industries and the growing respect among practical men for scientific methods. In almost every metallurgical establishment, trained analysts are a necessity. Pig iron, which was formerly made altogether by "rule of thumb," is now a chemical product; ores, flukes, and fuels must be analyzed, and, although only the larger establishments employ chemists steadily, this work draws largely upon the profession in all parts of the country.

In bleaching, in dyeing, and printing cloths, in the manufacture of soap, candles, and paints, in the extraction and refining of metals, in the manufacture of pharmaceutical preparations, in the making of soda-ash, acids, and fertilizers, and of various articles in household economy, chemical industry finds a wide application. The Pennsylvania railroad has its laboratory and corps of chemists. The Agricultural Bureau at Washington, the United States Geological Survey, various state surveys, and numerous agricultural experiment stations are similarly equipped.

Such service was formerly performed chiefly by college professors, but the amount of work gradually became so great as to create a demand for chemists who could devote their entire time to the work. The quality of water used for domestic purposes, the availability of water for use in steam boilers, the characteristics of mineral waters, the adulteration of food, drink, and medicines, the detection of poison, the analysis of ores, with the best process for mixing and improving them, are but a few of the problems referred to analytical chemists,

The opportunities which a career in this science offers to young men are sure to increase with the increase of the nation in numbers and wealth. It is not enough that chemists have accomplished wonders up to the present time. They must do more. It should be significant of future triumph that they are now able to make artificial cocaine, indigo, and bitter oil of almonds, so true to the natural product that it is almost impossible to detect the difference. It is one of the aims of the chemists of this country to compound a varnish that will be durable and cheap in cost. Calico-printing is another industrial specialty that our chemists are studying. The printing-mill proprietors are often obliged to send to England for the services of competent men. There is no valid reason which occurs to me why American experts should not master this problem, as they have so many others. A young man of ability, who is willing to keep on experimenting and reducing theories to practical tests, has a grand field for his talents.

The opportunities for a young chemist are, on the whole, better to-day than they ever were. One who makes himself genuinely useful where he is employed may reasonably expect to be advanced to the position of superintendent or manager. In general, the post of chemist is the only stepping stone to practical metallurgy or chemical manufacture. Competent assayers speedily find practical mining open to them as a livelihood. The salary of an analyst in a manufacturing establishment is from one to two thousand dollars a year, often with the privilege of taking outside work. To these advantages may be added the opportunity for making inventions.

The discovery of a substitute for madder has caused the great areas of land required for the cultivation of that material to be put to other uses. An apparently trifling application of another chemical principle has enabled the salt manufacturers of New York state to compete with the world in producing salt for dairy purposes. Another application has made possible the making of steel in quantities formerly undreamed of; and still another chemical invention is causing large investments of capital in making soda-ash. In almost all other professions there comes between the instruction in college and the earning of a satisfactory income a period of practical apprenticeship, but in chemistry a graduate has been trained in exactly the kind of work he will be called upon to do in practical life, and, therefore, loses no time in experiments.

To become a good chemist one must have a taste for physical science. Problems are sure to present themselves which only the student with his heart in the work will have the patience or ability to solve. Delicacy and accuracy of manipulation are natural gifts to

some men, but may generally be acquired by practice. At present every chemical analyst of note has been trained in an American or foreign scientific school. Assaying involves comparatively little scientific knowledge; but even in this field the well-trained chemist has great advantage, both in fertility of resource and in ability to extend his work over a wider field, over the man who has merely "picked up" his ideas of the subject.

Experts are becoming more and more serviceable to capital. Especially is this true in the examination and appraisal of mining, and in the determination of the value of chemical products, and the patents resulting therefrom. Capitalists make their investments practically on the advice of these trained experts, who, being thus in demand, are well paid. Many large fees are also paid by Boards of Health and the medical fraternity, or through them, for the reference of sanitary questions to chemists trained in the best processes.

As a preparation to a coarse in chemistry, common school education is needed, together with a knowledge of higher mathematics, algebra, and geometry. The deeper and broader the foundation of general culture, the better.

PHYSICS

Molecules.— A molecule is defined as the smallest particle of matter which can exist alone. It is to be conceived as the smallest division of matter which can be made, and that if the process of divison is carried further than that point the body will be broken up into its chemical constituents. Molecules are composed of atoms. The molecule is the unit of the physicist; the atom is the unit of the chemist. A substance is made up of molecules. Their arrangement decides whether the substance will be gas, a fluid, or a solid. Our knowledge of the molecule and of its behavior is expressed in four laws which are named after their discoverers.

(1) *Boyle's Law.*— A given mass of matter in a gaseous state under constant temperature exerts an increase of pressure per unit of area upon the containing surface proportionate to the decrease of the volume under pressure.

(2) *Charles's Law.*— If the pressure upon a given volume of gas be constant, but the temperature be varied, the volume of the gas will increase 1-273d of the volume which it occupies at zero centigrade, for every degree of centigrade for which the temperature is increased.

(3) *Avogadro's Law.*— All equal volumes of gases at the same pressure and temperature contain the same number of molecules.

(4) *Dalton's Law.*—When a mixture of gases are in a state of equilibrium, each gas acts as a vacuum to the others, and will behave as though no other gas were present.

As to the size of a molecule, Sir William Thompson (Lord Kelvin) has estimated that, if a drop of water were magnified to a size equal to that of the earth, the molecules would be something smaller than cricket-balls and larger than shot.

A force is whatever changes the state of rest or uniform motion of a body.

The property which every body possesses of preserving its state, whether of rest or of motion is called inertia. Whenever a body at rest starts to move, or when in motion it begins to stop or to change the direction of its motion it is under the influence of a force which overcomes its inertia.

Constitution of Bodies.—Bodies exist in three states: solid, liquid, or gaseous.

A solid is one whose molecules always bear the same relation of place and size. It always preserves the same shape.

A liquid is a body which accommodates its shape to that of the vessel in which it is placed. Its molecules pass freely over one another, and obey the law of gravity. Consequently a liquid body is found at the bottom of a vessel in which it is placed.

A gas is a fluid which however small in volume, is able to expand indefinitely so as to be able to fill any size of vessel however large.

Attraction.—The power which bodies exert of drawing other bodies to them is called attraction. It is the opposite of repulsion. Molecular attraction is the force which binds the molecules of a body together. This is strongest in solids, less in liquids, and wanting in gases. There is also the attraction of gravity which bodies exert upon one another at a distance. The attraction of gravity is proportionate to the mass. It is that force which causes unsupported bodies to fall to the ground. It keeps the solar system in equilibrium; causes the moon to revolve around the earth; and the rise and fall of the tides. There are also electrical and magnetic attraction.

Adhesion.—This is the force that causes bodies of different kinds to cling together. It is seen in the case of glue, nails, screws, bolts, etc. It is exerted between solids and liquids, between solids and solids, and between gases and solids. Two pieces of polished glass will adhere so intimately that often they cannot be separated without breaking. Friction is really adhesion between two surfaces. The greatest adhesion is to be seen in the case of cement. If a dry needle be carefully placed upon the surface of water it will be seen to float. This is because it rests upon a cushion of air which adheres to the

steel, and increases the buoyancy of the needle. Adhesion is the cause of capillary attraction.

Elasticity.— This is the property which all bodies possess to a greater or less degree of resuming their former shape when they are released from the action of a force which tends to distort them. The rapidity with which they resume their shape, together with the amount of distortion, determines the degree of elasticity. It is possessed in the highest degree in such substances as rubber, cork, and air. Yet solids generally possess it. Ivory possesses it, as may be shown by dropping, from a height of a few feet, an ivory ball upon a hard substance coated with moist black paint. Observe the size of the surface marked by the paint. Then gently place another portion of the ball upon the paint, and compare the size of the spots. The fact that the former is the larger shows that a greater portion of the ball was exposed to the action of the paint in the first case than in the second case. In other words the surface of the ball was slightly flattened by the force of the fall. When a body resumes its former shape quickly it is said to rebound. There is a limit to the elasticity of bodies. If the limit is exceeded, the body is either broken or permanently bent.

Density.— The quantity of matter contained in a unit volume is called the density. The unit volume is either a pound or a gram. The term density is largely replacing the expression specific gravity, which is really only the relative density of bodies compared with the density of water at 4° centigrade taken as the standard and called 1. It is found for example, that a diamond weighs 3½ times as much as the same volume of water. Therefore the relative density or the specific gravity of the diamond is said to be 3.5.

The relative density of several important substances is here given.

Iridium	22.4	Rock (Average)	2.7
Platinum	21.4	Aluminum	2.6
Gold	19.3	Sulphur	2.
Mercury	13.6	Magnesium	1.7
Lead	11.3	The Human Body	1.1
Silver	10.5	India Rubber	1.1
Copper	8.9	Alcohol	0.8
Nickel	8.7	Ether	0.7
Iron	7.8	Lithium	0.6
Tin	7.3	Air	0.0013
Zinc	7.2	Water-Vapor	0.0008
The Earth	5.6	Hydrogen	0.00009
Diamond	3.5		

The following is the method of finding the relative density or the specific gravity of solids. It consists in finding what an equal volume of water will weigh, and dividing this weight of water into the

actual weight of the body. The quotient represents the number of times heavier the body is than the same volume of water.

I. Weigh the body in air.

II. Weigh the body suspended in water. This gives the weight of the volume of water displaced by the body, as the body displaces its own bulk.

III. Divide the weight in water into the weight in air. The quotient is the relative density or specific gravity of the body.

The relative density of a liquid is most conveniently found by the use of a hydrometer. When any body floats in a liquid under the action of gravity, the weight of the floating body is equal to the weight of the fluid it displaces. This is the principle upon which the hydrometer depends. A block of ice is lighter than the same bulk of water. Therefore it floats. If the block is solid, it will float high. But if it is honey-combed and water can get into the body of it, it will become more nearly equal to the bulk of water and will float low or be partially submerged. A body floats high or low in a fluid, according as it is lighter than the fluid or more nearly equal to it. The hydrometer is a hollow glass bulb with a long slender stem, which is graduated or divided off into measurements. The balloon of the glass bulb has usually a little mercury in it to keep it floating upright. The hydrometer is immersed in the liquid and the relative density is indicated by the mark upon the stem in line with the surface of the fluid. The lighter the liquid the lower the hydrometer will sink, and, conversely, the heavier the fluid, the higher the hydrometer will float. Consequently the stem is numbered from above down. The marks are ascertained by placing the hydrometer in fluids of known heaviest and lightest density, marking the stem at the points of coincidence with the surface of the fluid, and then dividing the intervening space into the proper unit divisions. In addition to hydrometers for general use with all fluids, there are these for special fluids, as the alcoholmeter, for alcohol; barkometer, for tanning extracts of bark; lactometer, for milk; salinometer, for solutions of salt, etc.

Diffusion.— This is the power of mixture. Some liquids will not mix at all. Mercury and water do not mix; nor do oil and water. Diffusion is most marked in the case of gases. If carbon dioxide, one of the heaviest of gases, be placed in a jar, and above it, mouth downward, be placed a jar of hydrogen, the lightest of gases, it will be found after an interval that the laws of gravity have been set at naught. For the heavier carbon dioxide will be found mingled with the light hydrogen in the upper jar, and the lighter hydrogen is mingled with the heavier carbon dioxide in the lower jar. This is supposed to depend upon the kinetic theory of gases. It supposes that

the molecules of gases are always in a state of rapid motion. Regarding the molecules as very minute billiard-balls, when they come in contact with one another, they change either the force or the direction of their motion, and they are in this way buffeted about and intermingled.

Cohesion.—The force which binds the molecules of a body together is called cohesion or molecular attraction. When a stick of wood is broken, sawn, or split, the force of cohesion has been overcome.

Gravitation.—The attraction which causes an unsupported body to fall to the earth. When a body falls from any height above the earth it is always in a straight line which if produced would pass through the center of the earth. This attraction is exerted by and between the bodies. Two chairs upon a floor in the same room attract one another, but not sufficiently to overcome the friction; hence they are not drawn toward one another. Two bodies, one heavy, the other light, such as a bullet and a piece of cork, will fall to the ground in the same time if dropped from the same height. The force of gravity or the attraction of the earth acts upon both alike irrespective of their weight or size. But if one of the objects be a feather or light tissue-paper, it will not fall so quickly as the lead, because its downward motion is retarded by the resistance of the air, which very light objects cannot easily overcome but which does not so greatly affect the denser object. This can be proved by exhausting all the air out of a long glass and allowing a feather and a dime to fall from one end to the other of the tube. It will be found that btoh will fall together, as there is no air in the tube to resist the motion of the feather. Then it may be stated as another fact of gravitation that the length of time which it takes a body to fall to the ground does not at all depend upon the size, weight, or the material of which it is composed. It has been found by experiment that the distance through which a body falls in one second of time when acted upon by the force of gravity alone, is $16\frac{1}{10}$ feet. If a body falls for the space of two seconds it will fall through a greater distance during the second second than it does during the first. This is because it has gained a certain velocity during the first second, and, in consequence, it does not start from rest at the beginning of the second second, but with a certain velocity which it has gained during its previous second of motion. Similarly it will pass through a greater distance during the third second than it does during the second or the first second. The longer time it falls the greater will be its gain in speed. It has been found by actual careful experiment that a body falls $16\frac{1}{10}$ feet during the first second, in two seconds it falls $64\frac{4}{10}$ feet. Therefore it has fallen $48\frac{3}{10}$ feet during the second second. But at the

beginning of the second second it had a starting velocity of the $16\frac{1}{10}$ feet through which it had fallen during the first second, therefore its increase in speed during the second second is $48\frac{3}{10}-16\frac{1}{10}=32\frac{2}{10}$ feet. Now this number $32\frac{2}{10}$, or 32.2 as it is usually written, is an important number in calculating the distance through which a body will fall either in any number of seconds or in any given second. It is called the acceleration, which means the increase in speed. It is often indicated for brevity by the letter « g », which in physical formulas stands for the acceleration of falling bodies which is 32.2 feet. It will be noticed that the distance through which the body falls during the first second is $16\frac{1}{10}$ feet, and that this number is just one half of 32.2 feet. Consequently $16\frac{1}{10}$ feet is often called $\frac{1}{2}g$ or $\frac{g}{2}$. The following laws of falling bodies have been proved by experiment.

(1) A body which falls freely from rest, *i. e.*, it is allowed to drop and is not thrown, falls with a velocity equal to 32.2 multiplied by the number of seconds through which its fall has lasted. For example: It is required to know with what velocity a stone is moving at the beginning of the sixth second of its fall. It has been falling for five seconds. Therefore it is starting upon its fall at the beginning of the sixth second with a velocity of 32.2x5=161 feet.

(2) A body falling freely from rest will pass over a distance equal to 16.1 multiplied by the square of the number of seconds during which it has fallen. In one second it will fall 1^2x16.1=16.1 feet. In two seconds it will fall 2^2x16.1=64.4 feet. In three seconds it will fall 3^2x16.1=154.9 feet. In four seconds it will fall 4^2x16.1=257.6 feet.

By an application of the above rules it is possible to estimate the height of a cliff, by timing as accurately as possible the falling of a stone from the top. If a body is thrown down with an initial velocity, its speed at starting will be the same as though it had fallen freely long enough, under the action of gravity, to gain that velocity. This can be found by dividing the velocity at the start by 32.2 and then adding the number of seconds thus found to the time. Suppose a body is thrown downward with an initial velocity of 64.4 feet. How far will it have fallen at the end of four seconds? The initial velocity of 64.4 feet is the same as though it had fallen freely for two seconds, because 64.4 divided by 32.2=2. Adding this to the four seconds the result is six, and by applying the rule given above the result is 6^2x16.1=579.6 feet. But this is 64.4 feet too much, for it did not fall through the 64.4 feet of velocity with which it started. Therefore 64.4 must be taken from the result and the space through which it will fall in four seconds is 579.6–64.4=515.2 feet. This result can be obtained more concisely by means of the formula v' t gt^2 where v'=

the initial velocity; t—the time of falling, and g—32.2. Applying this to the previous question $64.4x4+\frac{32.2x16}{2}=257.6+257.6=515.2$.

If a body is thrown upward with a velocity, this retarding force must be taken into account. If a body is thrown upward with a force of forty feet per second, where will it be at the end of two seconds? If the force of gravity had not acted to pull it downward it would have gone upward 2+40=80 feet. But the force of gravity exerts a pull downward equal in two seconds to $16.1x2^2=64.4$. Therefore the actual height at the end of two seconds will be 80–64.4=15.6 feet, at the end of three seconds it would be (3x40)–(16.1x9)=120–144.9. As the force with which gravity would pull it down is greater than its initial velocity would carry it up, this shows that at some point in the third second, the object has gone up as far as gravity will permit, and then it began to fall.

If a ball be dropped from the topmast of a vessel in motion it will be found to strike the deck in precisely the same spot in which it would strike it if the vessel were at rest. In the latter case the ball would fall in a direct vertical line. But when the vessel is moving the path that the ball would take would be a curve compounded of the vertical fall and the onward horizontal movement of the vessel. This goes to prove that if a body is thrown horizontally forward, it will fall to the ground in exactly the same time that it will if dropped from the height of its horizontal path above the earth at starting. If it were possible to throw a marble horizontally at a height of four feet above the earth, and at the same time drop a marble from the height of four feet, it would be found that they would both come to the ground at the same time.

In the case of projectiles it can be easily seen that the distance which they can be thrown depends entirely upon the initial velocity with which they can be hurled. For the faster they go the farther they will go before being brought to the earth by the force of gravity.

HYDROMECHANICS

Hydromechanics is the science which treats of the mechanics of water and fluids, including gases. It is divided into:—Hydrostatics, which treats of the mechanics of fluids at rest; Hydrodynamics, which deals with the force of fluids in motion; and Hydraulics, by which the motion of water in pipes and canals is considered.

Hydrostatics.—(1) When a fluid is at rest under the action of gravity the pressure is the same at all points in any horizontal plane

below its surface. At all points in a horizontal plane one foot below the surface of the water the pressure is the same.

(2) The pressure on a horizontal plane in a vessel of water or other fluid at rest is proportionate to the depth. The pressure is usually calculated at so many pounds per square inch. The pressure depends upon the weight of a unit volume of the fluid. Let it be required to know the pressure per square inch exerted by water at the depth of one foot below the surface. A cubic foot of water weighs 62.4 lbs. A cubic inch of water would weigh $62.4 \div 1728$ (the number of cubic inches in a cubic foot). But in a column of water one square inch at the base and one foot high there will be twelve of these cubic inches piled one on top of the other. They will weigh $\frac{62.4 \times 12}{1728}$ or $\frac{62.4}{144}$. This is equal to 0.433 of a lb. Therefore the pressure per square inch at a depth of one foot is 0.433 lb. At a depth of two feet, it will be 2×0.433 or 0.866 lbs.; at ten feet 4.33 lbs.

(3) The pressure upon the base of a vessel is the same at all points regardless of the shape of the vessel. If the vessel is irregular in shape, smaller at the base than at the top, or smaller at the top than at the base, in all of these cases, the pressure upon the base will be equal to the weight of water contained in an imaginary cylinder or prism of which the base is one end, and with a height equal to the height of the vessel. The pressure at any part of the base per square inch will be the weight of a column of water one square inch at the base and as high as the greatest depth of water in the vessel. If the vessel is funnel-shaped and is one inch at the base and ten inches at the top, the pressure upon the base will be the weight of the column of water which is immediately above the base. The pressure of the rest of the water will be borne by the supporting side of the vessel.

HYDRAULICS.—*Pumps.*—The simplest form of pump is the lift pump. The principle upon which this depends is based upon the fact that by the use of proper machinery the atmospheric pressure is removed from the surface of the water. Everywhere over the surface of the earth at sea-level the atmosphere exerts a pressure of fifteen pounds upon the square inch. This force is equal to the weight of a column of water one inch square at the base and thirty-two feet high. If we take a glass tube one inch square and thirty feet high, and fill it with water and allow its base, which is open, to rest upon the surface of a vessel of water, it will be found that the water will remain at that height in the tube although both ends are open. It is kept from dropping back into the vessel of water by the pressure of the atmosphere upon the surface of the water in the vessel. The duty of the common pump is to relieve the pressure of the atmosphere from the

surface of the water and to allow it to rise to its height in a tube. It does not rise above thirty feet because of the friction upon the sides of the tube and also because it is impossible to get a perfect vacuum. The pump consists of a long tube extending down into the water. Into this tube is fitted as tightly as possible a plunger which is caused to move up and down in the tube by means of the handle of the pump. In this plunger is fitted a valve opening upward only. When the plunger goes down on the first stroke, the pressure upon the valve of the air below it in the tube opens it upward. Some of the air is exhausted from the tube and when the plunger rises and the valve closes, the air in the tube expands to fill the space, so that there is not so much pressure upon the surface of the water in the tube and the water rises a little way in the tube. Upon the next downward stroke more air is exhausted and the water rises a little higher. It is for this reason that a few preliminary strokes are needed before the water flows freely. When the water rises to the level of the plunger, the water forces the valve in the plunger upward and as the plunger rises it brings the water up with it as the weight of the water keeps the valve closed. For this reason the action of the pump is intermittent. That is, no water flows out of the spout during the downward stroke. By rapid pumping and short strokes, the intervals are so short that the flow seems to be continuous. Sometimes in the case of much-used pumps it is necessary to pour a little water down the pump to cause it to act. That is because the plunger which is made of leather has become worn and dry and is not air-tight because it does not quite fill the space in the tube. The water poured down upon the plunger fills these spaces for the moment long enough to exhaust the air from the tube. It may also have the effect of swelling the leather and thereby filling the space.

A Force Pump instead of having a spout for the escape of the water has a delivery pipe extending upward. By means of this water can be forced up to greater heights than thirty feet.

Pumps for use in mines and canals are of very large size. Some in use in the North Sea Canal in Holland will deliver 670 tons of water every minute with a lift of five feet. The pump disks are eight feet in diameter. Some in use in the Marshes of Italy deliver 2,000 tons per minute. One in use in a drainage system in Barbadoes has a disk of 16 feet in diameter.

The steam-fire engine is an elaborated style of force pumps which pumps the water from the hydrant and forces it through the hose. They have a plunge speed which causes the plunger to move through from 180 to 220 feet per minute.

Hydraulic Pressure.—The simplest form is the water furnished by falls and streams that have been dammed. The power depends upon both the volume of water and the height of the fall. The most notable use of water power is the "harnessing" of Niagara Falls and the conversion of that tremendous power into electricity. In the Niagara Falls and River about 18,000,000 cubic feet of water flow each minute through a fall of over 300 feet. This gives theoretically over 7,000,000 horse power. The power derived from the falls is used to drive street cars and to light the streets of Buffalo twenty-six miles away. And during the electrical exhibition in New York City, power from Niagara Falls was used to transmit electrical power to operate machinery.

The motive power is not the falls themselves but the water of the Niagara River drawn off by an enormous tunnel at a distance of about a mile above the falls. This tunnel is 6,807 feet long, 18 feet 10 inches wide at its widest part, and 14 feet wide at the base. The tunnel leads out of an enormous pit, 178 feet deep, 40 feet long, and 18 feet wide. The tunnel is 21 feet high and has a grade of from four to seven feet in every thousand. It is lined at the lower end with steel-plates and the rest of the way with rings of brick, all of which is to prevent the wear and tear of its powerful flow. The water thus drawn falls 154 feet. Although the whole of the machinery is not yet in place, it is intended that the water shall fall upon ten water-wheels, which will each revolve a 5,000 horse-power dynamo for the generation of electricity. After the water has done its work it runs off into the river some distance below the falls. The pit and tunnel are cut out of the solid limestone and over 1,000 men were three years in digging with the most improved appliances. The fact that these are dug out of solid rock has made the work more possible, for the force of water, falling 154 feet, would be sufficient to sweep away man's strongest masonry. The water-wheels are especially tough and revolve with incredible speed under the force of this mighty blow.

The hydraulic press was invented by Bramah in 1785. It depends upon the principle that a pressure exerted upon any part of the surface of a liquid is transmitted undiminished to all parts of the body of liquid and in all directions. The only limit to the power that can be exerted is that of getting machinery strong enough to withstand the enormous strain. A press consists of a strong cylinder supplied with a piston worked by a lever. From the cylinder leads a tube to the larger tank of water upon which the press is situated. As the pressure is applied by the piston upon the water in the cylinder, that pressure is communicated through the water in the tube to the greater

mass of water in the press. An idea of the force can be obtained in this way: If the area of the tube is one square inch and a pressure of ten pounds is applied to that square inch and is communicated to the larger volume of water in the tank which will be supposed to be three feet square, and to measure nine square feet or 1,296 square inches; each of the 1,296 square inches will receive a pressure of ten pounds and the upward pressure in the tank will be 12,960 pounds. All this is done by pressing merely ten pounds on the piston. By the application of much greater pressure and by making the tank of the press vessel larger enormous pressure is exerted. Its chief use is in baling cotton, and expressing oil from seeds. The hydraulic power is also applied to cranes and elevators. The power is so applied to cranes that one man can alone, raise, lower, and swing about in any direction the heaviest load with marvelous ease and precision.

Compressed air has entered into use as a motive power during the past century. It was used to drive drills in Mount Cenis and the Hoosac tunnels. Its chief use is in the Westinghouse brake which was invented in 1887.

Levers.— These are rigid bars of any shape that are operated upon by two forces which tend to make them rotate in opposite directions about a fixed axis. The axis is the fulcrum. In ordinary practice it is the block of wood upon which the lever rests. One of the forces is the resistance, the load on the weight that is to be overcome or lifted. The other force is the power that is applied to do the work. The distance from the fulcrum to the load is one arm of the lever, the distance from the fulcrum to the power is the other arm. The relation of these arms to one another constitutes the whole value of the lever as a machine. The principle upon which its working depends is put into practice by two children of very unequal weights who are playing "see-saw," with a plank placed over a log. The lightest child gets the most plank. The log is the fulcrum. The portions of the board between the fulcrum and each child are the arms. Each child becomes in turn as they go up and down the load and the power. The principle is that the length of each arm in feet multiplied by the weight at its own end must give an equal product in each case, to produce equilibrium. To be effective a lever must be so placed that only a short arm is on the load side of the fulcrum and a very long one on the power side. To exemplify the saving of power it may be asked "A load of 10,000 pounds is to be lifted by power applied by a lever. The fulcrum is one foot from the load and the power is applied at a distance of ten feet from the fulcrum. What power is needed?"

$1000 \times 1 = X \times 10$ or

$10X = 1000$

$X = 100$. Here it will be seen that one hundred pounds are capable of balancing or raising 1,000 pounds. Archimedes, the inventor of the lever, is said to have remarked: "Give me a place to stand and a lever long enough and I will move the earth."

The position of the fulcrum divides levers into three classes. In the first class the order is weight, fulcrum, power. In the second class, fulcrum, weight, power. In the third class fulcrum, power, weight.

The principle of the lever is widely applied. A pair of balance scales is a lever of the first class. The scale pans represent the weight and the power, and the point of support is the fulcrum. A pair of oars used in rowing also belong to this class. A man wheeling a wheel-barrow is an example of the second class, where the wheel is the fulcrum, the barrow is the weight and the man is the power. A pair of nut-crackers is also of this class, the hinge is the fulcrum, the nut to be cracked is the weight and the hand is the power. A pair of scissors or of shears is an example of the first class, when the rivet is the fulcrum.

Inclined Planes.—The second of the fundamental simple machines is the inclined planes. In considering its efficiency or power it is necessary to take into consideration the proportion of the height to its length. And these are considered thus: The power necessary to lift a weight is to the weight as the height of the plane is to its length. The less the height in proportion to the length, the less the power needed to perform any work. The term is used popularly to describe a steep railway ascent in a short grade where cars are raised by means of a wire rope operated by a stationary engine at the top of the grade as at Mahanoy City, Pa., or by means of special rails and engine wheels as on the Mt. Washington Railroad in New Hampshire.

Screw.—The screw is a fundamental simple machine. It is in reality an inclined plane rising around a spiral axis. While the inclined plane is used to overcome gravity alone, the screw is used to overcome resistance in some other form. In order to work with the greatest ease or with the least expenditure of power, the threads of the screw must rise very slowly and be close together. The commonest examples are the Jack-screw for overcoming gravity, the propeller-screw for overcoming the resistance of the water, ordinary wood screws for overcoming friction, and the screw-press for overcoming elasticity. By the pitch of a screw is meant the distance between the middle points of two adjacent or successive threads measured along the line of the axis.

The wedge is another application of the inclined plane. It is a triangular prism of hard wood or of metal and is driven into objects

to be split or between objects to be separated. The relation of the height, or square end to be struck, to the length decides the ease with which it may be driven; a long, tapering wedge goes much easier than a short, blunt one.

Wheel and Axle.— This is one of the primary mechanical powers and consists of an axle and a concentric wheel. A rope is attached to the wheel and the axle is revolved by levers. The wheel acts as a pulley.

The windlass is a form of the wheel and axle used for raising weights. The capstan for raising anchors, the winch for raising weights either by hand or by steam or electric power are variations of the same.

Pulleys.— These are simple fundamental machines. A pulley consists of a circular grooved piece of wood, called the sheave, which revolves in an outer piece called the block. The rope that runs around the groove of the sheave is called the tackle. The sole purpose of the pulley is to produce equilibrium. It may be used single or in combination. If a single pulley is used, the power is equal to the weight. The pulley may be regarded as a lever without arms. When pulleys are used in combinations the load is borne by all the blocks and less power is required to balance the load.

HEAT

Nature of Heat

When we stand in the sunshine, or before a fire, we feel hot; when we handle snow or ice, our hands feel cold. The cause of these sensations is called heat. When we feel hot, it is because heat is absorbed by our bodies, and when we feel cold, it is given off by them. What, then, is the nature of heat?

To answer this question let us see how heat can be produced, or generated. We know, that if we draw a cord rapidly through our fingers, they feel hot, and that if we rub a coin briskly with a piece of cloth, it soon becomes warm; if we take a nail and hammer it on an anvil, it soon becomes too hot to hold. In each of these instances, the motion of a body was checked or retarded. When the cord is drawn through our fingers, it moves less easily than it would if it were not gripped by them; and the more we retard its motion by gripping it more tightly, the hotter it makes our fingers feel. When the hammer strikes the nail on the anvil, its motion is checked by the nail, and the faster the hammer moves, the hotter

the nail becomes from the hammering. From these experiments, and from others similar to them, we see that whenever the motion of a body is checked, or retarded, heat is generated, and the body is made hot.

In explaining why heat can be produced in this way, it was formerly said that all bodies contain a substance without weight, called caloric, and that, when they were rubbed or hammered, this substance was given off by them. This notion was held until about the end of the 18th century, when it was shown by Benjamin Thompson, Count Rumford, that heat is given off by bodies, as long as they are rubbed. From this fact Count Rumford argued that heat cannot be a substance, because the quantity of any substance, present in a body, cannot be limitless. After a time, the supply of caloric would be exhausted, and rubbing could no longer produce heat.

The explanation that is now given of the production of heat by rubbing, or by striking bodies together, is that, while the motions of the whole bodies are checked, the small particles, of which all bodies are composed, are caused to vibrate very rapidly, and that it is these vibrations, which are too small to be seen, that produce the sensation of heat. This view of the nature of heat is in accord with Count Rumford's discovery, as you will readily see, for so long as the rubbing, or hammering, of a body is continued, it is natural to suppose that the vibrations of its particles, or molecules, as they are sometimes called, will continue.

Perhaps you find it somewhat difficult to grasp this idea, but that need not discourage you, for it is not very easy to comprehend at first. After you have seen how heat affects bodies, and have studied some of its uses, its nature will be better understood.

The Sources from which we Obtain Heat

You have already been told that heat is produced by rubbing bodies together, which is called friction, and by striking them together, which is known as impact. These, however, are not very important sources of heat. The most important source is the sun. Were it not for the heat that comes to us from the sun, this world would not be habitable. Not one plant or animal would be found alive on it; all the oceans and rivers would be converted into ice, and perhaps even the atmosphere, that surrounds the earth, would be converted into a liquid and frozen.

Next in importance to the sun as a source of heat, is chemical action. You have already been told that chemical action is the

cause of fire, and that, even when it does not produce fire, it is productive of great quantities of heat, as, for example, in keeping our bodies warm by means of the chemical action that takes place when we breathe. Fire, however, is undoubtedly the most valuable form of chemical action, as a source of heat; and it plays so important a part in our daily lives that it is worthy of special study.

Fire has been called by some the "chief servant of man," and man is the only creature that has learned to make fire his servant. The use of fire shows that man, even in the lowest savage tribes, possesses a higher degree of intelligence than the other animals, and the methods used by different tribes and races of men in making fire, as well as the uses to which fire is put by them, serve as an index of the degree of culture to which they have attained.

There have always been many natural sources of fire, such as volcanoes, burning oil wells, flashes of lightning, blazing meteors, and other less important phenomena. It was from these natural sources that men, in the savage state, learned the uses of fire, and long before they learned to write, they devised methods of making fire artificially. The earliest means employed by men in kindling fire, was, probably, the friction of dry sticks upon one another. This friction was sometimes produced by twirling a stick between the palms of the hands, and at the same time pressing the end down into a small depression in another piece of wood, resting on the ground. When this is done a tiny cone of dust soon gathers, smoulders for a few moments, and then bursts into flame. Instead of twirling the stick between the palms, some tribes learned to whirl it with greater speed by means of a sort of bow, the string of which was wound around the stick. In still other tribes, drawing one stick to and fro across another, was the method employed. All of these methods were necessarily slow, though it is surprising to see how short a time is required to produce fire by friction, if properly done.

From the making of fire by rubbing pieces of wood together, to its production by striking flint upon steel, was a greater advance, and those tribes who discovered the new method, or obtained the knowledge from their neighbors, did not delay in adopting it. From the flint and steel to the match of modern times was the final step, which was a long time in being made.

To trace the development of civilization in mankind by the multiplication of the uses of fire would be most interesting; but it would require too much space to attempt it here. We may, however, note a few of the ways in which fire enters into our daily lives. When we rise in the morning and prepare for the day, we wash with soap formed in caldrons heated by fire. The food we eat at breakfast is

cooked by fire, and is served in dishes baked by fire. Fire was used in extracting from their ores the metals of which our knives and forks are made, and in driving the sawmill in which the wood of our breakfast table was sawed. The house we live in was produced by the aid of fire; its chimneys are built of brick baked by fire, and the mortar that cements them together was formed from lime, obtained by burning limestone in kilns. Other kilns baked the tiles of the hearth, and dried the wood in the doors and floors. From fire-smelted ores were obtained the metal for the water and gas pipes, the bell wires, and every hook or nail used in the building. As with the house, so with its furnishings: Its carpets and curtains were made by harnessing a steam engine to machinery, and scarcely an article can be found in the house into the manufacture of which fire did not enter.

Of far less importance, as a source of heat, than fire, but of an importance that is steadily increasing, is electricity, the only source of heat that has not been mentioned. When a current of electricity passes through a body of any kind heat is produced. If the body opposes much resistance to the passage of the current, the amount of heat produced is large, and if the resistance offered by it is slight, the quantity of heat produced is correspondingly small.

The incandescent electric light affords a very good illustration of the heating effect of electricity. The slender filament, in the bulb of the lamp, affords such high resistance to the passage of the current that it is heated white hot almost in an instant.

The Effects of Heat upon Bodies

When a body is heated it nearly always expands, that is to say, it grows larger and takes up more room than it did before it was heated. In solid and liquid bodies, this expansion is never very great, though at times it is sufficient to serve very useful purposes. You may have seen blacksmiths putting iron tires on wagon wheels, and noticed them heat the tires, almost red hot, before putting them on. You would have seen, by examining the tire before it was heated, that it was too small to go on the wheel; but when it has been heated, you see it slip on very readily. Evidently the tire has been made larger by heating it. When it cools it shrinks to its former size, and, of course, grips the wheel very tightly, which was the result desired by the blacksmith.

Another very interesting use of the expansion of solid bodies by heat is that seen in the straightening of the walls of buildings that have bulged outward. Holes are drilled through the walls, and long

rods of iron are passed through the holes and across the building, leaving their ends projecting outside. By heating the rods they are made to expand, and iron plates are then screwed on their ends until they lie close against the outer surface of the walls. The rods are then allowed to cool, and they contract with such great force that they draw the walls of the building together to their proper shape. By heating some of the rods again, while others are holding the walls from springing back to their former position, the plates may be screwed still further along on the rods and the walls brought still nearer together. In this way, by repeating the process of heating some of the rods, while the others prevent the walls from settling back, and then moving the plates closer together on the heated ones, any degree of bulging may be corrected.

When liquids are heated, they expand very slowly, and usually at a rate that is quite uniform. An excellent example of this expansion is seen in a thermometer. Most thermometers consist of a very fine, hairlike tube which terminates in a bulb, at one end; both the tube and the bulb contain mercury. When the bulb is cooled, the mercury in it contracts, and some of the mercury in the tube runs down into the bulb. When the bulb is heated, the mercury in it expands and some of it is forced into the tube. By marking the height of the mercury under certain conditions, and dividing the space between the marks into small intervals, called degrees, we obtain a scale which shows the degree of heat, or temperature. The two points generally chosen to form the basis of the scale, are the height of the mercury, when the bulb is plunged into melting ice, which gives the freezing point, and the height, when the bulb is immersed in the steam from boiling water, which gives the boiling point. After these two points are fixed the scale between may be made with as many divisions as are desired. The most convenient number is 100, and that number of degrees is used in what are called Centigrade thermometers. (Fig. 1.) In these the freezing point is marked 0° and the boiling point 100°. In the thermometer that is most used in this country, called the Fahrenheit thermometer (Fig. 1), there are 150 degrees between the freezing and the boiling points. The freezing point is marked 30°, and the boiling point 212°. The point marked 0° on this thermometer is the height of the mercury when the bulb is placed in a mixture of snow and salt, called a freezing mixture. A third form of thermometer that is used in some countries is called a Réaumur thermometer. It has a scale on which the freezing point is marked 0° and the boiling point 80°. Of course each number of

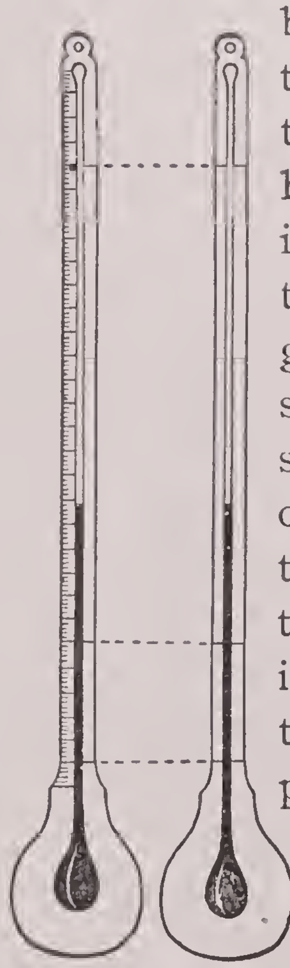


Fig. 1

degrees has a different meaning on each of these scales, and in order to prevent confusion the number of degrees is always written with a letter after it that shows which thermometer is referred to. Thus 50° C. means 50° on the Centigrade scale, 37° F. refers to the Fahrenheit scale, and 22° R. means 22° on the Réaumur scale.

When gases are heated they expand much more rapidly than solids or liquids, and all gases expand at almost the same rate, which is not true of either liquids or solids. This rapid expansion of gases, when heated, plays a very important part in a number of processes that will be spoken of in another place.

Some solids have the property of changing to liquids, when they are heated sufficiently. This change is called melting, or fusion, and you have seen illustrations of it in ice, and in some of the metals. There are a great many solids that can be melted by heat, and the degree of heat, or, in other words, the temperature, required to melt them, varies greatly with different substances. In the same substance, under ordinary conditions, the temperature at which fusion takes place is fixed. Thus 32° F. is the temperature at which ice melts, as well as that at which water freezes. It is therefore called the fusion point of ice, or the freezing point of water.

When ice is converted into water by melting, it shrinks in volume, and occupies less space than it did. A few other substances behave in the same way when they melt, but most substances expand when they change from the solid to the liquid form.

If a lump of ice be heated till it reaches a temperature of 32° F., it does not all turn to water at once. The process is a gradual one, and if the lump of ice is wrapped with a thick woolen cloth, to keep outside heat from affecting the ice, the melting will go on very slowly. In fact, if the ice were so protected from outside influences that no heat could reach it, no melting would take place. This shows that heat is required to melt ice, even after it has reached the temperature at which fusion takes place. The same fact may be shown by pouring warm water on ice. In melting the ice, the warm water loses its heat and becomes as cold as the ice itself. By observing the amount of heat lost by water in melting ice, it has been discovered that as much heat is required to melt a pound of ice at 32° F. as is required to raise the temperature of a pound of water from 32° F. to 176° F., almost to the boiling point. The water formed by melting the ice is no warmer than the ice itself, so the heat employed in melting it seems to have been lost. This is not true, however, for when it freezes, the ice gives off the same amount of heat that disappears in the melting process. The heat that disappears is simply hidden, hence it is called *latent heat*.

The fact that heat is required to melt ice, is the principle of "freezing mixtures," such as the ice and salt used in freezing ice cream. Salt has a strong attraction for water, and causes the ice to melt, but heat is required to melt the ice, and it must be obtained from the bodies near by. So if the cream to be frozen is placed in a tin vessel, which gives up heat very readily, and the ice and salt are then packed around it, heat will be withdrawn from the cream, which will freeze while the ice melts. By putting the ice in a thick wooden bucket, which gives up very little of its own heat, and prevents the heat of the air from affecting the ice, the freezing of the cream is quickened. It is on the foregoing principles that ordinary ice cream freezers are arranged.

All liquids that do not decompose when heated are converted into gases, or vaporized. This change may go on slowly at the surface, when it is called evaporation, or it may take place rapidly throughout the liquids, when it is called ebullition, or boiling. Evaporation goes on at all temperatures; but boiling does not begin until the temperature of the liquids has reached a certain point. This point varies greatly for different liquids, but for the same liquid, under the normal pressure of the air, the boiling point is always the same. By heating a liquid in a vessel, from which some of the air has been removed with an air pump, we find that it will boil at a temperature lower than its ordinary boiling point. By pumping an increasing quantity of air into the vessel, we find that the temperature required to boil the liquid is higher than the ordinary boiling point. Extensive experiments have shown that *the boiling point of any liquid is proportional to the pressure upon it.*

When liquids are converted into gases, by evaporation, or boiling, heat becomes latent, just as it did in changing ice to water, and the heat that becomes latent, in the vaporization of a quantity of water, is much greater than that which becomes latent, when the same quantity of ice is melted.

It is the fact that heat is rendered latent by the vaporization of liquids, that causes the evaporation of perspiration to cool our bodies, and that produces a pronounced sensation of cold when alcohol or ether is poured upon the skin. Both of the latter liquids evaporate very rapidly, and, in evaporating, they absorb heat from the skin and make it cold.

By subjecting to great pressure some of the substances, which are gases, at ordinary temperatures, and under the ordinary pressure of the air, and at the same time cooling them, they may be converted into liquids. Among the substances that have been so converted into liquids are ammonia, gas, carbonic acid gas, and even air itself. In order to keep these substances in the liquid form they must be kept under enormous pressure, for as soon as the pressure is removed they

evaporate or boil, and return to the gaseous form, as rapidly as they can obtain heat sufficient to vaporize them. In vaporizing, they reduce the temperature of everything around them to an exceedingly low degree. The evaporation of liquid air is so rapid that it freezes mercury in a few minutes, and will even convert liquid carbonic acid into a solid that is somewhat like snow.

The Transmission of Heat

The modes, by which heat is transferred from one point to another are known as *conduction*, *convection*, and *radiation*.

Conduction is that mode of transmission by which heat is transferred from one heated end of an iron rod to the other. It also takes place in liquids and gases, to a slight extent, but in them it is of but slight importance. In solids, however, conduction is the only way in which heat can be transferred, and it is explained in this way. When one part of a solid body, such as an iron rod, is heated, the particles of it are made to vibrate with greater rapidity than before, and they strike with greater force upon those lying nearest to them. These, in turn, have their rate of vibration increased, and strike harder upon those lying just beyond them. Thus, the vibrations of the particles at the end of the rod that is being heated are gradually communicated to those forming the remainder of the rod, until the heat becomes nearly uniform.

The readiness with which heat is conducted, by different substances, varies greatly. Metals are the best conductors, but their conductivity varies considerably. If two rods of the same length, but composed of different metals, as iron and copper, are both heated at one end and you touch them with your finger at the other end, you will find that after a few minutes the copper rod has become hotter than the iron rod. This shows that copper is a better conductor than iron. The clothing we wear is made of fabrics that vary greatly in their capacity for conducting heat. Wool fabrics are the poorest conductors, and linen the best, while cotton and silk lie between these two. Consequently, the best material for winter clothing is wool, because it allows less heat to escape from our bodies.

When heat is applied to liquids or gases, the particles nearest the source of heat expand, become lighter than the other particles, and rise, because the other particles press down around them and force them up. Other particles are continually being brought into contact with the heating surface in this way, and finally the temperature of the whole body of gas or liquid is raised. This mode of transferring heat is called *convection*. You will readily see that convection can

only take place in gases and liquids, because the particles of the body must be free to change their relative positions.

Convection is constantly going on, naturally, on the earth's surface, where it serves a most important purpose. Over some parts of the earth's surface, the sun shines with much greater heat than over others, consequently, the surface becomes hot and the air lying next it becomes heated also. This heated air rises, because the cooler air over the other parts of the surface presses under it and forces it upward. The cooler air flows in toward the heated regions, and produces the winds, which have so much to do with the distribution of rain, and, hence, with the growth of plants and animals.

Radiation is the way in which heat comes to us from the sun, and in which we are warmed when we stand in front of a fire. Just how heat is transmitted by radiation cannot be explained to you at this point, but will be made clear in connection with the subject of light. The most striking thing about radiation is, that by it heat passes through some bodies without warming them. There are many bodies that permit heat to pass through them in this way, but dry air absorbs very little of the heat that is radiated into it.

When bodies of different kinds are exposed to radiation, the amount of heat absorbed by them varies greatly. The readiness with which bodies absorb heat depends chiefly upon their color. Dark bodies absorb radiant heat much better than light-colored ones, and those, with rough, or dull surfaces, absorb it better than those having smooth, polished ones. This is easily shown by filling two bottles with water, one of which is clear glass, while the other is coated with soot, leaving them exposed for awhile to strong sunlight. After a time it will be found that the water in the bottle covered with soot, has become warmer than that in the bottle of clear glass.

If we fill the two bottles with warm water, and put them in a cool, shaded place for a while, we shall find, on examining them, that the water in the soot-coated bottle is now cooler than that in the other bottle. This shows that dark-colored bodies not only absorb heat more rapidly than light-colored ones, but also radiate heat better.

By applying the facts shown in the two experiments that have just been described, it is easy to see that light-colored clothing is better for both winter and summer than clothing of darker tint. For in hot weather, light-colored clothing absorbs less of the heat of the sun than dark clothing does, and in cold weather light-colored clothing retains the heat of the body better than the dark, because it is a poor radiator.

Heat Engines

At the beginning of this article, your attention was called to the fact, that by checking, or retarding, motion, it could be transformed into heat. Now we will consider the opposite change of heat into motion and the means of bringing it about. The production of motion by means of heat is by no means so simple a matter as the production of heat by merely rubbing, or striking two bodies together. Special machines are required to transform heat into motion, and they are known as heat engines. These heat engines are divided into a number of classes, such as steam engines, gas engines, and the recently invented liquid air engines.

Steam engines were the first of these forms of heat engines to be produced, and they have been made in many different forms, varying in size from an engine that can be hidden under a thimble, to engines weighing hundreds of tons. But the great majority of all these have a number of features in common. (See Fig. 2.) Each has a furnace, F, in which fuel, generally coal, is burned, a boiler, B, in which water is converted into steam, and, connected with the boiler, a cylinder, C, in which the steam causes a piston, P, to slide back and forth. The entrance of the steam into the cylinder is controlled by a valve, V, which is so arranged, that when the piston reaches one end of the cylinder steam enters in front of it and causes it to travel in the opposite direction. As the piston travels back and forth the steam enters first at one end of the cylinder, then at the other. The piston is connected with a wheel, F, in order to transform its to-and-fro movement into the more convenient rotary movement, and this wheel, which is called the fly-wheel, is very large and heavy, except in locomotive engines. Its great weight is to prevent sudden variations in the speed of the piston.

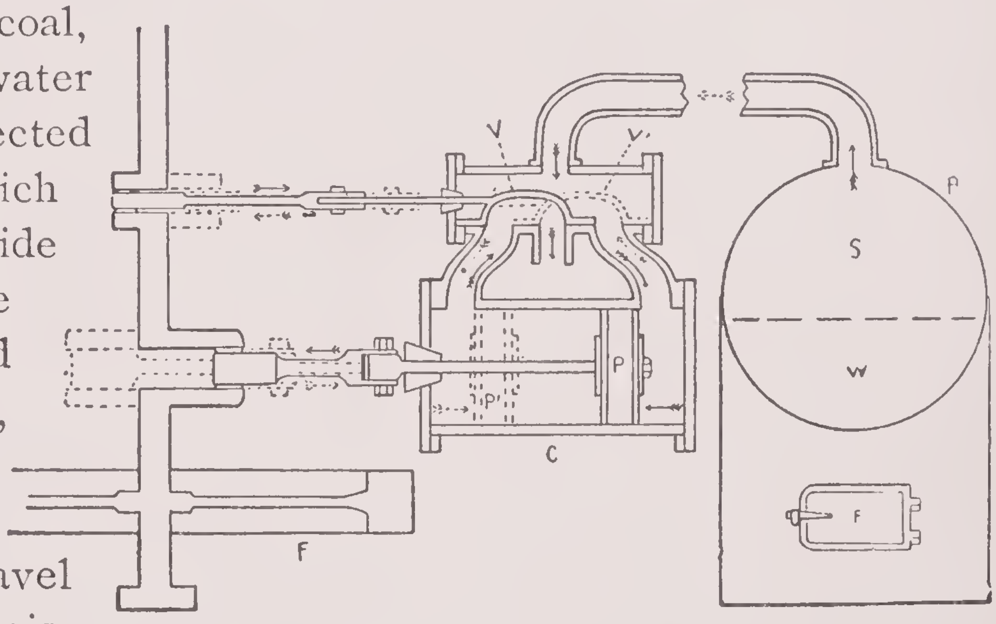


Fig. 2

In gas engines there is no boiler, because steam is not needed. There are a cylinder and a piston, however, and the motion of the piston is produced, by introducing into the cylinder, on one side of the piston, a mixture of gas and air, and exploding the mixture by means of a spark at the right moment. When the explosion takes place, the heat produced by it causes the gas and water-vapor, pro-

duced by the explosion, to expand with considerable force, and thus to drive the piston back in the cylinder.

Liquid air engines are so new that it is impossible to say with certainty what form they will take. There must always be a very strong reservoir for the liquid air, and a cylinder in which it will expand and cause a piston to travel back and forth, in somewhat the same way that the pistons do in a steam engine. No furnace is required, for air at ordinary temperature yields all the heat that is required to boil liquid air. This fact, that the heat of the atmosphere will be all the heat required for a liquid air engine, is the chief reason for the attention that is now being bestowed upon that form. The low cost at which liquid air is now produced makes it seem probable that it will be extensively used in engines.

Before leaving the subject of heat engines, something should be said about the way in which the power of an engine is measured. If we know the area of the piston in inches, the distance in feet that it travels at each stroke, the number of strokes it makes per minute, and the pressure of the steam in pounds upon each square inch of the surface of the piston, the power of the engine may be easily obtained by multiplying these quantities together. The number obtained in this way, will be the number of pounds that the engine can lift to a height of one foot in a minute. By dividing this number by 33,000 the power of the engine in horse power will be obtained, for an engine of one-horse power can lift 33,000 pounds to a height of one foot in one minute.

Animal Heat is the temperature of the body necessary for the sustenance of the physiological functions of the animal. It varies from that of the element in which the animal lives to a much higher degree. Animals are divided into warm-blooded and cold-blooded. The highest temperature is found in birds, sometimes 112° F. It ranges from 96° to 104° F. in mammals. That of man is about 98.2° F.

Black Heat is that condition of a metal heated, but not sufficiently to glow. Black-red heat is that condition in which the body begins to glow in daylight. Red heat and white heat are terms used to indicate the color radiated by metals and some non-metals when heated sufficiently high. Iron becomes malleable at a full-red heat and pasty at a white heat.

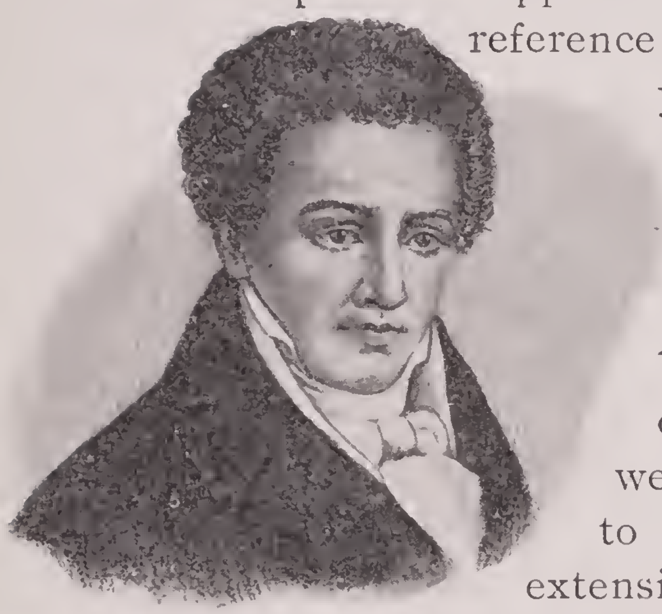
Specific Heat is the number of heat-units necessary to raise the temperature of a unit of mass through 1° of temperature. Water is the standard for solids and liquids. Water or air is the standard for

gases. It is the ratio of the quantity of heat required to raise a body one degree to the quantity required to raise an equal weight of water one degree. The measurement of specific heat is calorimetry. The unit of measurement is a calory. This is the heat required to raise one grain of water from 0° to 1° Centigrade.

Fusion is the act of rendering fluid or of melting by means of heat without the aid of a solvent. Certain crystals may be melted by heat with the aid of the water of crystallization which they contain. This is called aqueous or watery fusion. After the water of crystallization has been expelled some salts may be liquified by heat alone. This is called dry fusion. The point of fusion of metals is the degree of heat at which they liquify, and varies greatly in the several metals. The fusion is sometimes rendered easy by the use of soda, or borax, which is called a flux.

ROBERT FULTON

It was he who developed the steamboat.



In the latter part of the second century before Christ, a Greek engineer, Heron of Alexandria, described in one of his professional treatises a turbine wheel or cylinder to be operated by steam. No practical application was made of the device, and though occasional reference to it during the succeeding seventeen hundred years proves that the mechanical powers and uses of steam were in the minds of scientists and engineers, we meet nothing definite till we come to a treatise by the Italian, Della Porta, in 1601, wherein is described a pumping engine to be worked by steam power. This engine did not come into operation, but nearly a century later its principles were applied by Savery, an English mining engineer, to a pump for freeing mines of water, which came into extensive use, and is a historical relic of vast interest, as the earliest application of steam power to the uses of industry

Twenty years before the invention of the Savery steam pump, a French scientist had proposed the cylinder and piston arrangement, familiar in hand pumps, as a desirable principle for the application of steam as an industrial power. Twelve years later, another Frenchman, Papin, an ingenious mechanician, carried the proposition forward to a practicable stage, but combined it with other features that proved impracticable, so that the piston engine got no further along at that time. If Savery knew of the proposed cylinder and piston engine, which is unlikely, he ignored it, for the Della Porta engine, which he developed, is not of that piston class. But by 1705, the Savery engine was so well known to Europe that Papin took up the subject again, devised various improvements which eventually made their way into the general development of the steam engine, and among them that of the internal fire box, which, in the guise of fire tubes penetrating the mass of water in the boiler, gave to the world the fast-running railway engine.

Coincident with these later efforts of Papin, an English engineer, Newcomen, successfully applied the cylinder and piston construction

to pumping engines, to which the industrial use of steam had thus far been confined, and there the matter virtually rested for some sixty years. Only a brisk and expanding industry like that of coal mining could stand the expense and inefficiency of steam power, which, for the one purpose of freeing the mines of water, was yet the cheapest and most efficient agent known.

It was in 1769 that Watt, the genius of steam, set free the fettered giant. By adding the condenser he made steam cheap, and by variously improving and compacting the whole construction, he brought the mechanism of steam power within the limits necessary to an application of it to rail and river transportation. Thus the epoch of the Watt engine became the initial point of the era of the steam locomotive and the steamboat.

As early as 1782, John Fitch, a native of Connecticut, employed as a surveyor in Kentucky, conceived the idea of steam navigation while exploring western rivers. It took so strong a hold upon him that he applied, though without success, to the legislatures of Virginia and several western states for aid in testing and developing his proposed steamboat. In 1786 a company was formed to exploit his invention, and an experimental boat was built and tested on the Delaware. Grants were obtained from the states of New York, New Jersey, Pennsylvania and Delaware, for the exclusive right of the navigation of the waters of those states for a term of years, and the company procured further capital and prepared to work its valuable franchises. In the summer of 1790 it had a steam packet in regular operation on the Delaware River, but the enterprise proved a financial failure and the company went to pieces. Fitch then struggled on for eight years longer, sinking deeper into penury and despair, and finally killed himself in a fit of despondency, on learning that he had lost his title to valuable Western lands, while pursuing the phantom of steam navigation.

In 1774 James Rumsey, a millwright in Maryland, made a limited and experimental application of steam to boats ascending a river against a strong current, which is interesting as the earliest example of steam navigation. It was also the foundation of the claim he afterward made against the priority of Fitch, and the damaging agitation which he set afoot against the franchises obtained by Fitch's company. In 1787, after the trial of Fitch's boat on the Delaware, Rumsey gave an exhibition of his own device on the Potomac. Unable to make headway at home, he obtained the means to go to England, then a more promising field. In 1792 he exhibited a steamboat on the Thames, and died at London near the close of that year, leaving his invention still in the experimental stage. His « Short

Treatise on the Application of Steam," authoritatively fixes his true place among the pioneers of the steamboat.

William Symington, a Scotch engineer and machinist, made at Edinburgh, in 1788, a marine engine for a twin-hulled pleasure boat on Dalwinston Lake, using a paddle wheel between the decked-over hulls. This was a little later than the experimental boats of Fitch and Rumsey, but was the practical beginning of steam navigation. In 1801 he exhibited a successful stern-wheel steamboat on the Forth and Clyde Canal, but for fear that the wash would destroy the banks of the canal, the proposed use of steam on canals was promptly abandoned.

The use of steam at high pressure had been contemplated nearly half a century before Watt's great improvements, and these included high-pressure engines; but he deemed high pressures theoretically unsound, and his great authority carried general sentiment and practice with him, in looking to further improvement of the low-pressure condensing engine to develop steam power to its highest limit. Nevertheless, Oliver Evans, in America, and Richard Trevithick, the gifted Cornishman, were successfully developing the high-pressure, non-condensing engine, and in 1804 Trevithick was running the first steam locomotive on a colliery railway in Wales.

We are now prepared to discern and estimate Fulton's place in the history of steam navigation, beginning with Heron's theoretical disclosure of steam as a motive power twenty centuries before, and coming down past Savery's pumping engine a century before Fulton, and past Papin's internal fire boxes, Newcomen's piston engine, Watt's condensing and low-pressure engine, the steam-operated boats of Fitch, Rumsey and Symington, which died practically in their infancy, to the high-pressure engine as developed by Evans and Trevithick for the service of the ingenious on land or water. As Emmett, a great advocate, so eloquently said of the steamboat in his defense of Fulton's New York franchise before the Supreme Court of the United States: —

> "Genius had contended with its inherent difficulties for generations before, and if some had nearly reached, or some even touched, the goal, they sank exhausted, and the result of their efforts perished in reality and almost in name."

Fulton was an Irish-American, born in Pennsylvania, in 1765, and, as one of five children in a poor family, he obtained but the elements of even a common-school education in a still primitive time and locality. From his earliest years he had two natural aptitudes which, unrestrained and undiverted by either classical or professional training,

shaped and dominated his life — art and mechanics. To draw pictures and to have the run of shops where tools and implements were used in the humble products of the Lancaster County of those days, were his childish delights. Drawing led him to painting, and painting took him to Philadelphia, which Franklin's impulse had long since established as the center of science, art and literature in the Western world. There, at seventeen, the War of the Revolution just over, and the continental metropolis throbbing with present prosperity and unbounded expectations — there, where the wealth and fashion, the culture and taste of the new nation had concentrated themselves, the young genius obtained orders for portraits, and sale for the landscapes that represented the varied charms of the inexhaustible region of the Wissahickon. There he remained four years, his vogue still unexhausted, and there he might have remained till compelled by nature to exchange the delights of the Quaker City for the inferior pleasures of some other world, except for that chance which plays so great a part in the lives of men.

He had settled his now widowed mother on a little farm in Washington County, and on his way back to business at Philadelphia had paused for a short stay at the Warm Springs, to see and be seen of his wealthy and distinguished patrons. They told him that his native genius needed Old-World cultivation, and advised him to begin with England, which, though broken with politically, remained the cynosure in all else. They provided him with letters to Benjamin West, the Pennsylvania Quaker boy, who had reached the highest professional and social position at the British metropolis, and West liked his artistic promise and his amiable personality so well, besides being touched by the resemblance of Fulton's early days to his own, that he took him into his household. Though West had no love for the United States, born, as it had been, of rebellion against the Crown that he revered, his attachment to his native land, which was Pennsylvania and her only, and to all who claimed nativity there, was strong throughout his life.

As a resident pupil of West, the young painter had the best possible introduction to the artistic and the social world of the great capital. After several fruitful years in London, he took up his residence in Devonshire, fertile in landscape studies and dotted with homes of the country nobility and gentry, with family portraits to be painted for ancestral halls. Here he became acquainted with the accomplished Francis Egerton, third and last Duke of Bridgewater, renowned for his celebrated canals, and with the eccentric, intractable and wayward Earl Stanhope, devoted to science and mechanics. The intimate friendship to which these great noblemen and famous

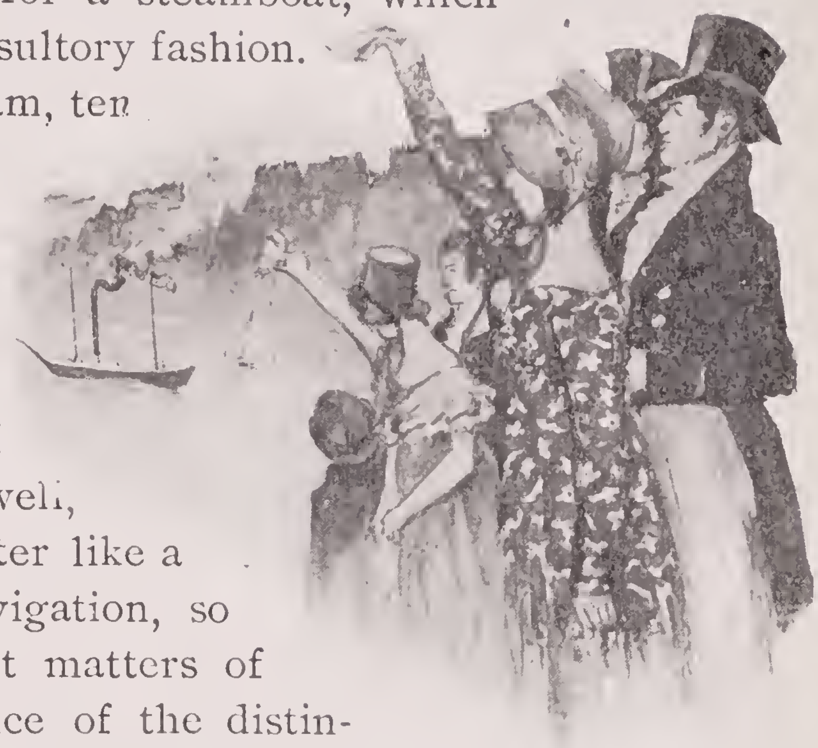
men of science admitted him, attracted by his genius and amiability, fanned into flame his natural love of the mechanic arts, and thenceforth the painting of landscapes and portraits makes but little figure in his occupations or preoccupations. From the example of the Duke, he could learn to sacrifice both fortune and personal comfort to the realization of great ideals, and from that of the Earl, that rank, high political station and the claims of family, are but as dust in the eye that fixes itself upon the clear light of science. The Bridgewater canals inspired him, in 1793, with the idea of the application of steam to the propulsion of boats, which never left him and which he never abandoned, and in which his faith was as strong at the very beginning as in years afterward, when his own realization of the conception had revolutionized inland transportation. This original faith and enduring constancy are to be regarded in a just estimate of his fame.

In 1797 Fulton went to Paris and took up his residence with Joel Barlow, a Connecticut Yankee, who divided his time between eccentric inventions, patriotic and humorous poetry and confidential diplomacy for the American government. Barlow had a notion of under-water explosives by which the French nation might overcome the superiority of the British navy. Into this new field, Fulton entered with an ardor that might have delighted his friend Stanhope, except possibly for the unfriendly purpose of it. From the river bank, he and Barlow propelled and directed the quickly devised Fulton torpedo, troubling the surface of the Seine by its explosion from beneath, and occasionally frightening the washerwomen and boatmen; but the British fleet remained safe. Fulton soon perceived that the operators, as well as the torpedo, must go under water, and this conclusion led him on to the devising of submarine boats. It led him also to the study of mathematics and chemistry as necessary adjuncts to submarine warfare, and to an acquirement of the French and German languages, as auxiliary to the principal arrangements for blowing up the power of the British empire. While Napoleon was meditating his project for the great "Army of England," afterward encamped for months at Boulogne, in sight of the dazzling cliffs of Albion, but destined never to cross the silver streak between, Fulton had progressed so far with his under-water torpedo boat as to propose to the Emperor the construction of a submarine fleet, by which to clear the intended path across the channel from British war-ships. The project was examined by a committee of naval experts, rejected, and consigned to the limbo of the Ministry of Marine.

Fulton thereupon left France and returned to his own country, then busy with Jefferson's projects of coast defense without the

expense of building and maintaining a fleet. Congress voted him five thousand dollars for an experimental submarine boat, but refused further aid, on the advice of the Navy Department.

Fulton now returned actively to his plan for a steamboat, which for some thirteen years he had pursued in a desultory fashion. From what he had seen and heard at Birmingham, ten years before, he decided to have an engine made there, at the works of Boulton and Watt, of the condensing and low-pressure type; with some modifying suggestions of his own, adapted to the necessary style of vessel and the tidal characteristics of the Hudson in the vicinity of New York Boat and engine fitted each other well, and in 1807 the little "Clermont" rode the water like a thing of life, solving the problem of steam navigation, so that all the things which lay beyond were but matters of industrial and commercial detail. The influence of the distinguished Chancellor Livingston had procured for himself and Fulton a franchise for the exclusive navigation of the waters of the state by steam power, which brought the steamboat into prompt and extensive use, and the example was followed by quite a number of the other states, whose franchises, however, were granted to their own citizens.



In 1811 Fulton was appointed a member of the Canal Commission at New York, an office for which he was eminently qualified, and in 1814 he built an experimental steam vessel for the navy; but the early termination of the war with England put off any conversion of the navy into a steam fleet. He died in February, 1815, long before the expiration of the monopoly granted to Livingston and himself.

ELIAS HOWE

He lightened woman's burden with the sewing machine.

Sewing is one of the oldest and most necessary of the industrial arts. Man cannot trace his history back to a time when it was not in use. Being as simple as it was indispensable, it happened that, in the division of industry which always marks the growth of civilization, the sewers became among the poorest paid of wage earners. Hood, in the "Song of the Shirt," has told us, more vividly than volumes of prose could tell, the wretched and hopeless plight of the underpaid seamstress. By means of the hand-plied needle, she clung for a time to the edge of civilized life, her feeble hold ever liable to be broken by the slightest casualty. During the later period of her existence, to individual anxiety was superadded the fear of general extinction by the arrival of the long threatened sewing machine. According to the popular idea at that time, a few score of these voracious thread-eaters would do the work of all the thousands of hand sewers, and these thousands, being already on the lowest rung of the industrial ladder, and hard pressed to keep a footing there, were the most helpless class of all the hand workers whom machinery was assailing from every side.

So far back as 1755, an attempt had been made to improve the art of hand sewing by pointing the needle at both ends and placing the thread eye in the center, but this device did not prove practicable. The next important inventor of a sewing machine was a French provincial tailor, in humble circumstances, named Thimonier. He did not have the eye-pointed needle, but he used a crochet needle that hooked a loop of thread, which it passed through the previous loop. None of the experts in such things were particularly attracted by it, and the Thimonier machine was already dead when the inventor died in 1857, in extreme poverty. Three years after the invention of the crochet needle machine, the true sewing machine was invented by Walter Hunt, a New York mechanic, who had no knowledge of the French device. The Hunt machine had the eye-pointed needle, the thread-carrying shuttle, and the double or lock stitch. It was a completely practicable machine from the start, and much time and skill, and

some money, were spent in experimenting with it and improving its mechanical details; yet it was neither patented nor brought to public notice, and Howe, who came into the field several years later, had never heard of it.

Howe was born in 1819, in Massachusetts, one of the eight children of a farmer who also carried on a grist mill. At six years of age he joined his elder brothers and sisters in the home-practiced industry of making by hand, cotton cards of leather and wire. When a little older he helped his father at the mill, being always too frail for farm work, and in winter time he attended the district school. He worked in the mill till he was sixteen, and there acquired a taste and an aptitude for machinery. One day the tale of a returned neighbor who had been on a visit to bustling Lowell and its great cotton mills, set fire to the imagination of the young Elias, and after a time the father, seeing how the current of the son's thoughts was running, consented that the youngster should go to Lowell and make a venture in the busy world. He obtained employment in tending and attending to cotton mill machinery, and though his propensity to pore and potter over improvements lost him the name of a steady workman, his cleverness was so far recognized as to always assure him a job. But in 1837 came the severest financial panic and era of commercial depression that the country had ever known, and Howe lost his situation. He went home for a time, and then got employment in a machine shop at Cambridge, where his cousin, Nathaniel P. Banks, afterward distinguished in public life, was at work, and where there happened to be an opening for Howe's talents in the making of a new hemp-carding machine. At the age of twenty-one he married, removed to Boston and there got work as a machinist. At Boston, he had his first conception of the sewing machine, which began to engross his interest and to render fixed attention to his trade impossible. His father, meanwhile, had removed to Cambridge, where he had a little shop for preparing the material for palm-leaf hats. Howe and his family moved into the father's house, and in the garret a lathe was installed for the making of a model of the sewing machine. By doing odd jobs, as his services were called for, he managed to provide for his family after a fashion, but his soul was possessed by the new invention. Poor as his means and prospects were at best, they were blotted out entirely by the destruction of his father's shop by fire.

Howe had already convinced himself that the machine would work, and that, when others saw it work, it would take the world by storm. But he was unable to buy the small quantities of iron and steel needed for the making of the working machine by which the world was to be stormed. He figured out a least expenditure of five

hundred dollars, under the most favorable circumstances, as necessary to demonstrate the value of his invention, and he seemed to have as much chance of ever getting it as of getting five millions. But a thrifty wood and coal dealer named Fisher had his fancy kindled by the machine and became infected by Howe's enthusiasm for it; so that, after hearing the latter's plans, he agreed, in exchange for a half interest in the invention, to furnish the five hundred dollars, provide a workshop at the top of his own house, and board Howe and his family. This burst of fortune came upon the inventor in the closing days of 1844, and all the rest of that winter and far into the ensuing spring, Howe worked all day, and very often all night, improving the details of construction and contriving away the difficulties that would unexpectedly spring up to mock the theoretical perfection at which the machine had arrived. One April evening, in 1845, Howe was able to show his backer a good seam, four yards long, sewed on the machine. That was the first of red-letter days, and the second came the following midsummer, when Fisher, with renewed confidence in the machine, still further improved, invested in the material and cutting out of a suit of clothes for himself and another for Howe, and the latter did all the sewing so well and strong that both agreed that the sewing would outlast the cloth. Howe and Fisher now had a good machine, and early in the next year they had a good patent on it, and were ready for the storming of the universe.

Howe took the machine to Boston and made his first attack on the tailoring trade. The machine and its work were declared to be admirable, and the inventor's assurances that future machines would do even better and faster work were freely accepted; but the argument was unanimous that the faster and better the work, the more rapid and complete would be the ruin of the tailoring business, and no merchant tailor would invest a dollar in the invention. Fisher, unprepared for this reception of a thing that he had supposed the world was going to fall down and worship at sight, dolefully withdrew from the enterprise, and Howe and his family went back to his father's house.

Howe put the sewing machine away, and became a locomotive engineer, at which employment he continued till his health, never good, and made worse by excessive work and worry, broke down and threw him back on his invention as his last resource. He conceived, as Fulton had done after like experiences with his steamboat invention, that England, as a richer and more advanced country, was a more promising field than his own, and sent his brother there with a better constructed machine than the first. The brother sold the British right to the invention to a corset and umbrella maker in London for twelve hundred and fifty dollars, and sent word to Elias to come over and

enter the service of the British proprietor, at a salary of fifteen dollars a week. Howe went over and afterward sent for his family; but in eight months he gave up his situation. The employer seems to have been a harsh and grinding man, and his views of Howe's peculiarities of temperament and habit were not kindly. Howe got money from home to send his family back, and remained in London, where he thought he saw opportunities ahead, which were not realized. By pledging his model and his letters patent, he got the price of a steerage passage to America, and arrived destitute at New York, where he found a letter awaiting him conveying the tidings that his wife was on her deathbed from consumption. Several days were lost in obtaining the fare to Boston, but Howe got home in time for the final scene. After this came the news that his few household goods, shipped from London, had gone down with the ship bringing them to America.

While Howe had been struggling with misfortune in England, the sewing machine had been making its way in the United States. Even the newspapers had been talking of the new wonder and so bringing it to further notice, and Howe began the manufacture and sale of the machine in a small way at New York with the aid of a partner. In August, 1850, enough suits were commenced to cover all the important forms or cases of infringement on his patent, and the first favorable decision was obtained nearly four years later. He obtained a seven years' extension of the patent, under a law which then existed in behalf of meritorious inventors who, from exceptional causes, had failed to obtain a reasonable opportunity of compensation during the original term of fourteen years.

Two great stages in the long and toilsome journey had now been passed. The invention had proved to be all that was claimed for it, and the validity and breadth of Howe's patent rights had been determined. The third stage would be the coming of the invention into general use, but that was still uncertain — so uncertain that when Howe's partner died, his heirs sold his half interest to Howe for a small sum, which the latter paid from other than mercenary motives. As the use of the machine increased, so did the resistance, often riotous, of alarmed workers; which was further incited by sentimental philanthropists and political demagogues, and by a considerable amount of popular sentiment, sincere though ignorant. Physical violence and moral intimidation together proved a barrier to the use of the sewing machine, in those large establishments where its public utility could be best and soonest displayed; yet its success in small industrial establishments, which could escape violence and intimidation, was so marked that large employers of labor had to stand up for right and reason; and all forms of opposition, interested and disinterested,

sincere and sinister, had to give way. When the sewing machine got its fair and free field, it acted as mechanical improvements have always acted. It cheapened production, increased consumption, enlarged employment and wages, bettered the physical, mental and moral status of the workers, and multiplied material blessings to all mankind.

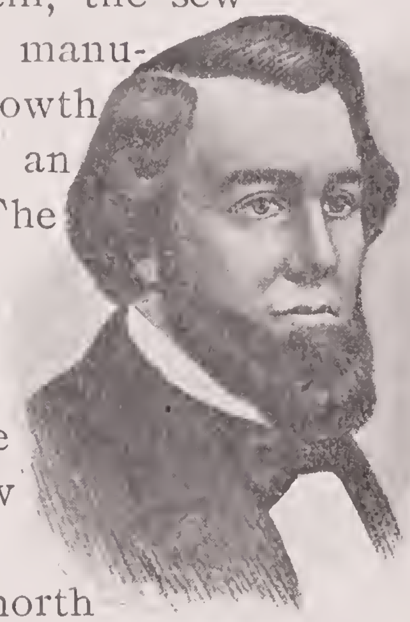
The fourth and final stage of the great invention was yet to come, and it came at last. The lifelong pauper, into whose soul the iron of penury had entered as, happily, it enters the souls of few, was destined to die a millionaire, and to live one before he passed to the chosen but unconscious company of the immortals. In face and figure he resembled Franklin in his later years, and a latter-day Franklin his admiring though rather belated countrymen were disposed to consider him. Having fought him to a finish in the courts, his rivals surrendered gracefully and he met their advances generously, for he was not a covetous man. If his royalties amounted to two hundred thousand dollars a year, that was because of the eagerness of the people for the sewing machine, and not of his desire for money. In the midst of the Civil War, with the eleven insurgent states making no returns, his income rose to the enormous figure of four thousand dollars a day, so much was the sewing machine in demand for clothing and equipage for the Union army and navy, and for making good in part the diversion of so much of the productive power of the country to the business of slaughter and destruction.

Howe was a true patriot and spent his new wealth freely in the national cause. When men for the army became more needed than dollars, the millionaire enlisted as a private for the sake of example; for his original constitution and his subsequently wasted health quite unfitted him for the ordinary duties of a field soldier. But a detail as an army mail carrier saved himself and the situation, and Private Howe was preserved to the active list. In the intervals of carrying the mail, he cashed the pay rolls of his regiment when the government, as repeatedly happened, was out of funds and the army paymaster had become a superfluity. He died at Brooklyn, New York, where he had finally fixed his home, October 3, 1867.

ROBERT McCORMICK

At his word the farmer hung up scythe and cradle.

In no branch of industry is the wonderful progress of a century more clearly shown than in farming. The labor saving and money saving machinery that has been devised, covering all the processes of agriculture, would be no less bewildering to the farmer of a hundred years ago, than would the flying railway train, the sewing machine or the telephone. The enormous business of manufacturing grain and grass harvesting machines had its growth from a seed of thought which sprang up in the mind of an humble Virginia farmer, nearly a hundred years ago. The success of the grain reaper was a stimulant to inventive genius, and other devices to lighten the toil of the farmer, quickly followed in its train. No doubt the actual growth of the crops will remain in the hands of nature, but there is very little else connected with the farm that is not now done by machinery.



Robert McCormick, whose grandparents came from the north of Ireland, was born in Rockbridge County, Virginia, in 1780. His mind early showed a bent for mechanics and invention. Even as a boy, he was always trying to find an easier and better way to do things. About 1809 he conceived the idea that a machine could be made that would cut grass and grain. In the development of this idea, he thought and worked and experimented for sixteen years, before he had produced a machine with which he was willing to make a test before the world. He had the experience common to great inventors. His friends and neighbors knew what he was trying to do. They had no faith in his scheme and declared with one consent that Robert was a foolish dreamer, who was "not quite right in his head." But McCormick was unmindful of their scoffs and went steadily forward, confident of final success.

In 1825 the first reaping machine was put to the test in a field of grain. It was rudely constructed, when compared to the beautiful and perfect mechanism of to-day, but its general form and principle were essentially the same as those of the present machine. It ran on two wheels, with a platform in the rear of the cutting apparatus to receive the grain. McCormick tried various devices for cutting the

grain. One of these was a system of rotary saws, which revolved past the edge of a stationary knife. The saws were driven by belts from a cylinder, which was turned by the revolution of the main wheels. Another cutting device was an arrangement of curved sickles, against which the grain was forced by a vertical reel. The reel was similar to those now in use, the purpose of which was to sweep the grain against the cutters, and when cut, to deliver it on a platform, whence it was carried by an endless apron and deposited on the ground by the side of the machine. The first reaper was not practically successful, except to demonstrate the fact that it would cut grain. This fully justified the faith of the inventor and encouraged him to "go on to perfection." It contained the principle and the main features of the grain-cutting machinery produced after seventy-five years of development, and warrants the claim made for McCormick, that to him belongs the credit for originality of thought, priority of invention, and the conception and construction of the first machine to actually cut grain.

Between 1825 and 1830, McCormick applied himself diligently to the task of perfecting his machine. He was sure that he had the correct principle, and needed only the proper mechanical devices for its application. He made many improvements, the most important of which were the vibrating sickle and the horizontal reel. By this combination, the reaper became successful. Those who had made sport of him and his long, patient labors, were now quick to recognize its value as the greatest labor-saving implement which the world had yet seen. The improved machine, except in its minor details and appliances, was very much like the reaper of to-day. The driver, however, did not sit on the machine, but rode one of the horses.

For many years McCormick worked away, constantly improving his harvester, but its progress in the world was slow. Most people were incredulous, and were loath to invest their scanty means in machinery of yet uncertain value and practicability. A manufactory was established in Cincinnati, but only a few reapers had been built, up to the year 1844. In that year the number reached twenty-five; in 1845, fifty; and in 1846, seventy-five. From this time the increase was rapid, by reason of the improvement of the machine and its introduction in large grain-growing communities. From this modest beginning, dates the vast business of manufacturing grain and grass-cutting machines and other implements to lessen the labor of agriculture, which now employs tens of thousands of men and many millions of capital.

While engaged upon his reaper, the fertile mind of McCormick produced several other inventions which proved of practical value. Among these were a hemp breaker, a thresher, a clover sheller, a hillside plow

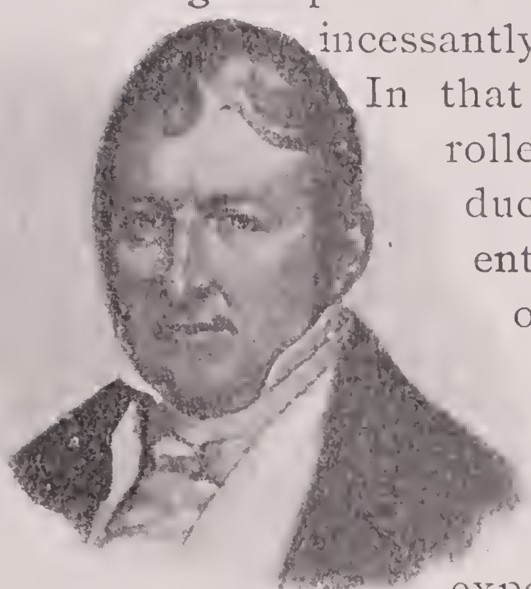
and an improved water power. In the early thirties, Mr. McCormick made what proved to be the mistake of his life. He invested a large part of his means in an iron manufacturing plant. Business was prostrated by the financial panic of 1837. At the time of greatest stress, McCormick's partner drew from the bank all of the firm's money, and then put his property out of his hands. Failure followed and all the obligations fell upon McCormick, who could recover nothing from his dishonest partner. He was a man of sturdy honesty, and, with the assistance of his sons, he paid every dollar of the indebtedness. In 1846 he was prostrated from the effect of exposure to a storm, and death came to him suddenly.

Mr. McCormick left three sons, Cyrus H., William S. and Leander J. Soon after the father's death, these formed a partnership and removed to Chicago, where they established the business of manufacturing reaping and mowing machines and other implements of agriculture. This has grown in half a century to its enormous proportions of to-day. The McCormick reaper is known all over the world. The only important feature that has been added since the days of Robert McCormick, is the ingenious device which takes the grain from the sickle, binds it into convenient sheaves, and drops them along the pathway of the machine.

ELI WHITNEY

Who solved a problem for the growers of cotton.

In 1792 Eli Whitney, of Massachusetts, graduated from Yale College, when twenty-seven years old. His ability to graduate, and the years lost from his early life in getting to college, are alike explained by the circumstance that his means of support and his college expenses were provided entirely by the labor of his own hands, incessantly continued while he was slowly making his way.



In that year when Eli Whitney, diploma in hand, was enrolled as a son of "Eli" Yale, the United States produced a cotton crop of two million pounds, raised entirely in South Carolina and Georgia, and of which one-fourth only was the contribution of Georgia. Of this crop, one hundred and eighty thousand pounds figured in the export trade of the United States. A century later than this college graduation, than this crop of two million pounds, and this export of one hundred and eighty thousand pounds of cotton, the American cotton crop footed up over four billion pounds, of which more than three billions went abroad. This multiplication of the crop in a hundred years by upward of two thousand times, and of the export by more than sixteen thousand times, is fundamentally, and chiefly in every other way, explained by the inscription on a tombstone at New Haven, which in full reads as follows:—

"ELI WHITNEY,
INVENTOR OF THE COTTON GIN."

Cotton growing in the United States, otherwise than as a petty experiment or venture, dates from about 1770, by which time the demand for cotton, caused by the Lancashire inventions of the weaving shuttle, the spinning jenny and the spinning frame, was causing anxiety to English and Scotch cotton manufacturers, and awakening hopes in the breasts of South Carolina and Georgia proprietors, whose lands were not swampy enough for rice culture, that cotton might prove to be the "money crop" they needed, in addition to the crops raised for the supply in kind of their families and negroes. The

lands which could not be used for rice were well suited to cotton, and the introduction of machinery in the cotton manufacture had opened up a practically unlimited and perpetual market for cotton goods all over the world, if only the raw cotton could be laid down cheaply enough at Liverpool, the cotton mart of the world. The one unfavorable circumstance lay wholly in a certain perversity of nature. The cotton plant was prolific in seeds, which embedded themselves tenaciously in the bolls. The separation of the seeds by hand was a tedious and therefore costly process, one pound of cleaned cotton per day being the average work of the slaves.

The average value of the pound of cleaned cotton was a quarter of a dollar, and considering that this had to afford a profit, after charging against it the value of the capital invested, and the whole cost of planting, cultivating, picking, cleaning and packing, it is not surprising that the profit was seldom to be perceived, and that oftener than otherwise the cotton cultivator was sinking his capital for the sake of the ready money obtained for his bags of cotton. The condition of affairs, and the effect upon them of the cotton gin, were thus afterward juridically stated by Mr. Justice Johnson, of the Supreme Court, himself native to the situation and locality he described: —

"The whole interior of the South was languishing, and its inhabitants emigrating, for want of some object to engage their attention and employ their industry, when the invention of this device at once opened views to them which set the whole country in active motion. From childhood to age, it has presented to us a lucrative employment. Individuals who were depressed with poverty and sunk in idleness have risen to wealth and responsibility. Our debts have been paid off, our capitals have increased and our lands have trebled themselves in value."

Whitney was born in 1765 and spent his early years on his father's little farm, helping about in summer and attending the district school in winter. In the intervals of farm work, he found employment at nail making, from which, as his dexterity with tools increased, he rose to the manufacture of women's hat pins and men's walking sticks, and eventually to the mending, in tinker fashion, of jewelry, and, in simple cases, of clocks and even watches. It was his good fortune to have had his mind fixed early on a definite purpose, which was to go to college. He was twenty-three years old before he was ready to execute this purpose, and then he lost a year by a long and wasting illness. But in 1789 he entered Yale, and in New Haven during term time, and here and there in New England during vacation, he got jobs of teaching and mending and metal working, and so kept his head above water till he graduated. He was

then past twenty-seven, and was deemed accomplished enough to become tutor in the family of a Georgia planter. On arriving at Savannah, he found that the place had been filled, but he was hospitably received by the widow of General Nathaniel Greene, who had bestowed her hand, and the estate given by Georgia to the general, upon another husband. Here Whitney resided for the time being, to the mutual satisfaction of all parties, and Whitney had begun the study of law, when his generous hostess, perceiving his mechanical facility, explained to him the plight they were in about the seeding of their cotton, and so plied him with compliment and importunity that Whitney, stirred by pride, chivalry and gratitude, became deeply interested, and as eager to solve the difficulty as the planters themselves. Passing the cotton bolls between crushing rollers had been tried and was even then beginning to be practiced; but seed fragments clung to the cotton and the slimy juice of the crushed seeds adhered to it, making the cotton "dirty" and low priced. The seeds must be removed whole and with the least possible injury to the fiber in tearing them out.

Whitney's first model was made entirely by himself in ten days after he had fairly set to work on the problem before him. It was a small affair, but satisfied him that he had his invention substantially complete and operative. Four months later, in April, 1793, he had a working model finished, so long a time being necessary by reason of the scarcity of material and mechanics, which compelled him to do most of the work himself. This model would clean fifty pounds of cotton a day. Essentially, the machine was a revolving cylinder turned by a hand lever and thickly studded with obliquely set, stiff, wire bristles, which permitted the cotton to pass through, beneath the cylinder, while the bristles forcibly brushed out the seeds.

Unlike the case of most inventions, the cotton-growing industry was waiting eagerly for this one, and as soon as the knowledge of Whitney's invention had spread about the neighborhood, his model was stolen in the night, and the manufacture of "gins"—abbreviated from the term "engine"—began. The widow Greene's new husband, who was to be an equal partner in the invention, decided that heroic measures must be taken to preserve to the partnership its prospective gains. The patent must be obtained as soon as possible, and even before the formalities of examination and allowance, and of issue by Thomas Jefferson, Secretary of State under President Washington, could be completed, Whitney must go to Connecticut and there arrange to manufacture gins rapidly enough to meet the demands of the cotton-growing industry.

In the summer of 1793, Whitney arrived at Philadelphia, the seat of government, to apply for his patent; but the yellow fever was raging, the government had fled and scattered, and it was winter before the patent could be obtained. There were already two other claimants for the honor and profit of the invention, and to gin the crop of 1793 the planters were ready to deal with anybody, patent or no patent. Cleaned cotton was worth an average of thirty cents a pound, there was no limit to the export demand for it, and cotton cleaned by gin would afford a large profit to the grower.

Whitney got the manufacture of gins started at New Haven, but then one misfortune after another came. He had a severe illness, and for a long time could not look after the business. The scarlet fever came among his workmen, and caused much further loss and delay. The moneyed partner had become tied up in the Yazoo land speculation, and Whitney was obliged repeatedly to borrow money, at growing rates of interest, as the necessity increased and the security declined. His partner's letters helped the borrowing, if not the paying, for they represented the cotton-growing country as run mad for gins, and begged Whitney to scour New England, New York and Pennsylvania for mechanics to be brought to New Haven, to increase the output.

Though the original purpose had been that the firm should have a supply of gins in operation by the winter of 1793, it was the late spring of 1794 before they had any, and they had but thirty-eight in operation in the winter of 1795, a third only of the number urgently required. In the spring of that year, the factory at New Haven had taken fire and been destroyed with all its contents, including Whitney's business papers, tools, materials and machines in construction. His partner had written on hearing of the fire: —

> "I will devote all my time, all my thoughts, all my exertions, and all the money I can earn or borrow, to encompass and complete the business we have undertaken. . . ; It shall never be said that we have lost an object which a little perseverance would have attained."

Further to encourage Whitney, he pressed him to proceed at once to rebuild and remanufacture; to offer twelve per cent per annum interest to lenders who could see the early future as they saw it, and, above all, to conceal the real desperation of their present circumstances. The partner was paying five per cent a month on his own borrowings, to keep his land investment afloat. In one direction he was useful to the embarrassed firm, for he worked up a sentiment in favor of something being done by the South for the man that had done so much for the South. The state of South Carolina,

raised by the cotton gin to immediate prosperity, boundless prospective wealth and a visible pride, led off with a grant of fifty thousand dollars by the legislature. North Carolina granted a percentage on the value of the use of gins for five years, and collected and paid it. Tennessee followed North Carolina as to the grant, but neither collected nor paid it. Georgia, where the battle of the gins had raged from the beginning, neither gave nor promised anything. Virginia and Kentucky were not interested, and there was then no Mississippi, Louisiana, Florida, Arkansas or Texas. Most of the money obtained from the two productive grants went in suits to enforce the patent right against infringers. A rival maker substituted saw-like teeth for Whitney's stiff wire bristles. The crushing roller gin was improved, and for a time attained a considerable use for low-grade cotton.

At the beginning of 1796, the firm was running upward of thirty gins in Georgia, and had put ten thousand dollars into sites for the gin houses. Whitney was still engaged in the factory work at New Haven, when, in April, his partner wrote him that news from London was that the cotton manufacturers in England had turned against ginned cotton, that the ginning process in Georgia had come to a standstill, and that he was receiving the condolences of a few real friends over the entire failure of so promising an invention. "Hasten to London," the letter said, "if you return immediately; our fortune—our fate, depends upon it." Whitney, however, was tired of the whole business, and was already contemplating the more attractive industry of making firearms by machinery. In 1798, the imminence of war with France, and the possibility of war ultimately with England, made the government ready to close with his offer to turn out army muskets and pistols, of uniform and approved standards, at an unprecedented rate. Then began that series of contracts which gave the forces of the United States the best arms then in the world; made this country down to the present time preëminent in the manufacture of firearms; afforded Whitney the fortune, if not the fame, that his great invention had denied him, and built up an important manufacturing village, appropriately named after himself. He had long been the greatest citizen of New Haven, and one of the foremost in the state, when he died there, in 1825, after passing his sixtieth year.

The wonderful economic results of the cotton gin, within a century after its invention, have been told in brief fashion. It made cotton growing so profitable that after using up all the adaptable wild, waste and worthless land in the two Carolinas, Georgia and Tennessee, the cotton culture spread into and gave value to the adaptable lands of Alabama, Mississippi, Louisiana, Florida and Arkansas, and ultimately Texas.

LIGHT

What Is Light?

In the preceding article on Heat, you were told that the transmission of heat by radiation would be more fully explained when we came to speak of light. The reason for postponing the explanation was that it is not really the heat, but the light, that is radiated. When light falls upon bodies it heats them, and the heat, so produced, is said to have been radiated.

To explain how light comes to us from the sun, we must suppose one of two things, either that light is composed of exceedingly small particles, that travel all the way from the sun, and enter our eyes, or that there is some substance, occupying the space between the earth and the sun, that transmits light. For many reasons, the latter supposition is the one that is now believed. The space between the earth and the sun and, in fact, all space, is thought to be filled with an exceedingly elastic and perfectly transparent substance, that is called ether. The nature of this ether is such, that it is believed to penetrate all of the ordinary substances with which we are familiar, and to fill the spaces between the molecules, of which they are composed. Even liquids, and hard solids, like iron and glass, have spaces between their molecules, into which the ether penetrates.

On account of its great elasticity, ether can easily be thrown into very slight and extremely rapid vibrations, which it transmits, in all directions, with a speed so great that it is almost impossible for us to form any conception of it. Some of the vibrations of the ether have the property of acting upon our eyes, so as to produce the sensation of sight, and these vibrations are called light.

By methods, too complicated for description here, the speed with which light waves are transmitted through the ether has been measured many times, and it has been found to be about 186,000 miles a second. At this rate, eight minutes are required for the transmission of light from the sun, and one and one-third seconds for the transmission of light from the moon.

How Light Is Produced

Having learned what light is, let us now see how it is produced. You have been told that ether penetrates all substances, and fills the spaces between their molecules, consequently, when the molecules of bodies are thrown into vibration, the ether between them must also be made

to vibrate, and when the vibrations become sufficiently rapid, they produce the sensation of sight. It has also been said, that when the molecules of bodies are thrown into rapid vibration, the bodies become hot, and we find that the converse is true, that is, in hot bodies the molecules are always in rapid vibration, and the hotter the body, the more rapid the vibration of its molecules. Naturally, then, we should infer, that when bodies become very hot, they ought to give off light. This we know from experience is true, and almost all the light we have is given off by hot bodies. The sun, from which almost all our light is derived, is so hot, that it is surrounded by the gases of many substances that exist as solids on the earth. Among these are the metals sodium, potassium, magnesium, and iron.

There are a few sources from which light is obtained without being produced by any considerable amount of heat. The lightning bug, or firefly, for example, seems to produce light that is accompanied by little or no heat; but men have not yet found out how this is done, and practically all of the artificial sources of light require the production of heat before light can be obtained. Only those vibrations of the ether that have a certain degree of rapidity can effect the eye and produce sight, and, for this reason, comparatively little light is given off by substances that are heated until they glow. They are like a piano player who sounds all of the lower notes on the piano, in order to get up to one of a certain pitch.

Rays of Light

Whenever vibrations are set up in the ether, at any point, they are transmitted along straight lines in all directions, from the point of which they were produced. A single line of vibrating particles, in the ether, is known as a *ray*. A number of rays, that are emitted from one point, are said to form a *pencil*. A pencil of light may be produced by holding near a candle a screen, that has a round hole in it. Sometimes rays of light are brought together in a point, as may be done by means of a burning glass, and one of these bundles of rays is known as a *convergent pencil*. The pencil shown in Fig. 1 is a *divergent* pencil, in which the rays are caused to diverge or separate.

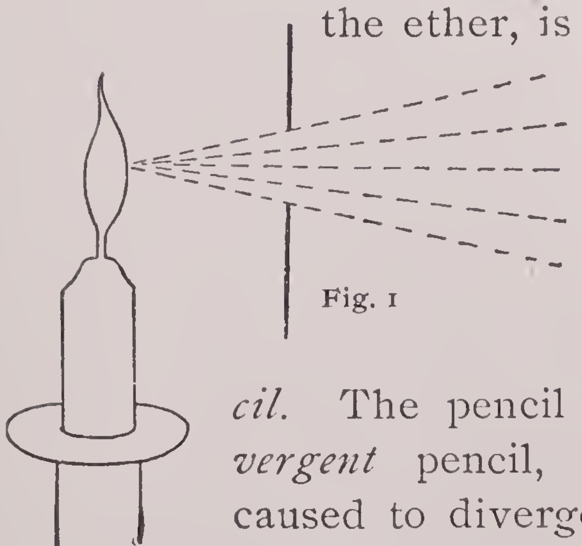


Fig. 1

A bundle of rays that lie parallel to each other forms a *beam*. (Fig. 2.) The rays that come to us from the sun are practically parallel, hence are said to form beams.

Fig. 2

Shadows

When a screen, through which light cannot pass, is placed in the path of light rays, the space beyond the screen is not lighted, and is called a *shadow*. This is shown in the diagram (Fig. 3), in which P is the point from which the rays start, and S is a screen placed in the path of the rays. The dark space beyond S is the shadow produced by the screen. The edges of a shadow that is formed by placing a screen in the path of rays from a single light-giving point are sharp and clearly marked. Such shadows are produced by electric arc lights. Most sources of light are of larger size than the arc lights, and the shadows produced by them are not so clearly defined. In Fig. 4, L represents a light-giving body, and S is a screen. Rays of light coming from the top of the body T are excluded from the space between points B and D, but they reach the space between A and B. On the other hand, light from R, the bottom of the luminous body, is excluded from the space between A and C, but illuminates the space between C and D. Consequently, the space between B and C receives no light at all from the body L, and, in spaces A B and C D, the light is partly excluded. The space from which all the light is excluded is called the *umbra*, and the surrounding space, from which part of the light is excluded, is called the *penumbra*. The lines that separate the umbra and penumbra are never clearly defined, so the exact limit of a shadow formed by a luminous body cannot be determined.

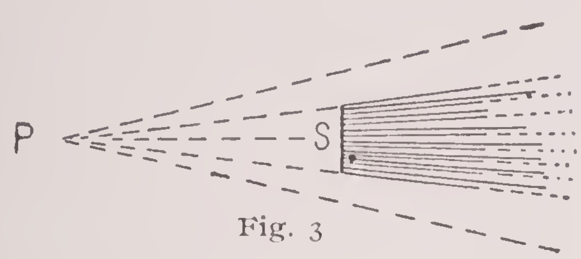


Fig. 3

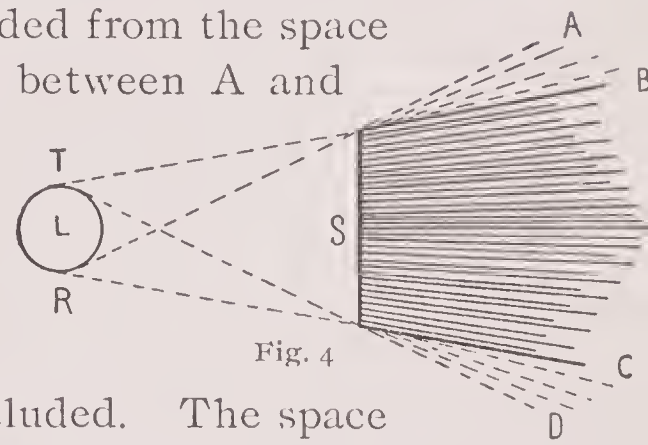


Fig. 4

Eclipses are merely shadows on the surface of the earth, formed by the passage of the moon between the sun and the earth, or formed on the surface of the moon, by the passage of the earth between the sun and moon. The former is commonly known as an eclipse of the sun, and the latter as an eclipse of the moon.

The Reflection of Light

We know that when light falls on smooth, polished surfaces it is reflected by the surface, so as to appear to come from some point behind it. If we take the trouble to note the angle made at the surface by the ray that strikes it, and also the angle made by the reflected ray, we shall find that the two angles are equal. That is, "the angle of incidence is equal to the angle of reflection." This

same rule was found to apply to the reflection of sound waves. There is this difference, however, between the reflection of light and of sound: sound waves are reflected from rough surfaces as well as from smooth, but light waves are reflected from smooth and polished surfaces, such as the surface of a mirror or of still water.

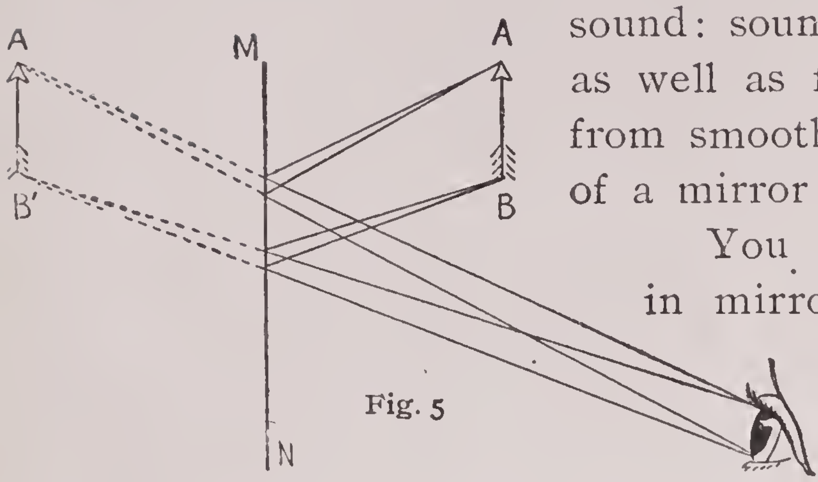


Fig. 5

You may have wondered how images are formed in mirrors, and, unless you know something about the behavior of light, this is difficult for you to understand. By reference to the diagram (Fig. 5), however, you should now be able to understand it without great difficulty.

The rays of light coming from the point of the arrow A are reflected at the mirror, MN, and appear to come from the point A^1 behind the mirror. In the same way the rays from B appear to come from B^1. If you were to look behind the mirror for the image A^1 B^1 it could not be found. For this reason it is called an *imaginary*, or *virtual*, image.

The images formed by flat or plane mirrors are always virtual images, and they are of the same size as the object. If light from an object falls upon the surface of a curved mirror, the image produced is either larger or smaller than the object, and it may be imaginary, like those in plane mirrors, or it may be a real image, that is, an image that will be formed upon a screen, if it is held in the proper position. The formation of images in curved mirrors would form an interesting subject for study, but their description would require too much space to be inserted here. You may get some idea of how the curved surface of a mirror affects the images produced in it, by looking at the image of yourself that is produced in the inside of a polished watch case. The inside of the outer case is concave, while the outside of the inner one is convex, and, in the former, you see a magnified image of yourself and, in the latter, the image is reduced in size.

The Refraction of Light

By the refraction of light is meant a bending of the rays. It is most frequently observed when light passes from air into some other transparent body, or from some transparent body into air. You have seen an illustration of refraction, when a stick has been thrust into a pool of water, or when you have put a spoon into a glass of water. The bending of the spoon, or stick, that seemed to take place at the surface of the water, was due to a bending of the light rays that

came to your eye, from the part of the spoon or stick that was covered by the water. The same thing may be shown by holding a thick piece of glass, obliquely, between your eye and a pencil, in such a way, that part of the pencil is seen through the glass and part through the air only. The part seen through the glass will appear to be shifted to one side, and the pencil seems to be broken at the edge of the glass. The reason for this peculiar appearance may be understood from the diagram (Fig. 6), in which the parallel lines, M O and N P, represent the sides of a piece of glass. The heavy line, A B C D, represents the path of a ray of light through the glass. The small cross lines represent the front of the ray of light. You will notice that the lines representing the wave front, while it is traveling through the glass, are not parallel to those representing the wave front, outside the glass. This is due to the fact that the light wave cannot travel so rapidly through glass as it does through air. You see that the wave strikes the glass obliquely, and one side of the wave front enters the glass before the other does. The part of the wave that enters first has to travel more slowly than the part that is still traveling through the air and, consequently, by the time the other side of the wave enters the glass, the side that entered first has gone only a short distance. The wave front has accordingly been turned out of its former position, and into the position shown, by the lines inside the glass. When the farther side of the glass is reached, the side of the wave that entered the glass first emerges first, and as it travels faster through air than through glass, it swings around, before the other side of the wave emerges, until the wave front is restored to a position parallel to the one it occupied before it entered the glass. While the course of the wave is then parallel to the course followed by it, before entering the glass, it does not return to its original course, and, if it enters the eye of a person at D, it seems to have come from E, instead of A, the point from which it started. If a pencil were at A, therefore, the part seen through the glass would seem to be at E, and the part seen through the air would be seen at A, causing the pencil to appear to be broken at the edge of the glass.

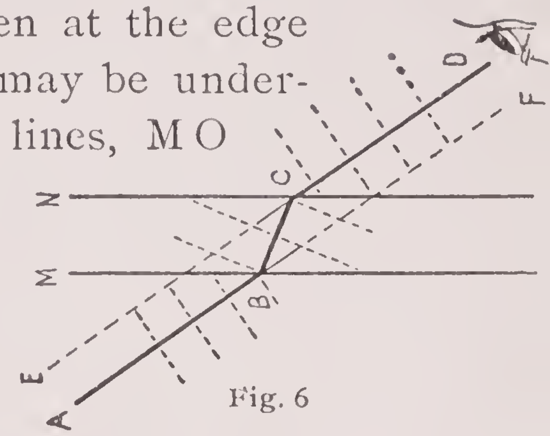


Fig. 6

A simple experiment that shows very clearly the bending of light rays by water is illustrated in Fig. 7. Drop a coin into a china bowl, and raise the bowl until its rim hides the coin. Then pour in water, and when the bowl is nearly full the coin will come into view.

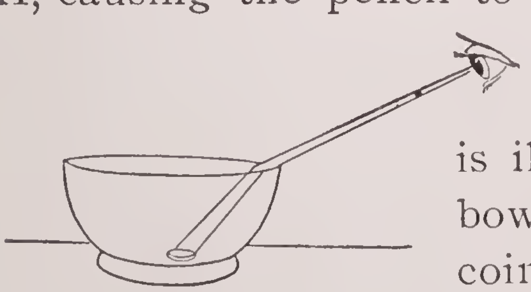


Fig. 7

If a ray of light is made to pass through a triangular prism of glass of the form shown in Fig. 8, the ray, on emerging from the prism,

does not come back into a course parallel to its original course. Instead, it is always bent toward the base of the prism. Thus, the ray AB, instead of going on to E, passes through the prism along the line BC, and, on emerging, travels along the line CD. If, instead of a prism, the light passes through a circular piece of glass, called a lens, which is thicker in the middle than at the edges, such as is shown in Fig. 9, the rays that pass through any part but the center are bent out of their courses and turned toward the center.

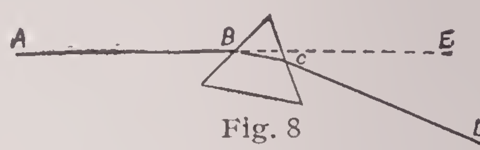


Fig. 8

Parallel rays are so much refracted by a lens of this kind that they are brought together at a point F, called a *focus.* If the sun's rays, which are parallel, are brought together in this way, they may produce heat enough to set fire to paper, or, if the lens is large enough, even to wood.

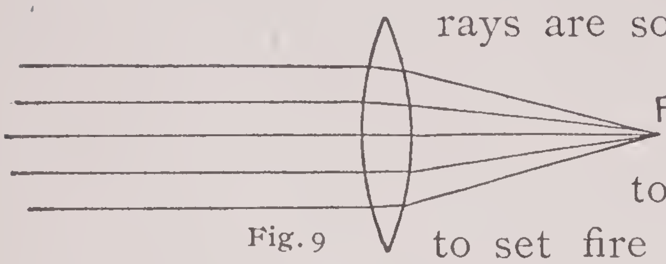


Fig. 9

This property of the lenses, of the shape shown, has caused them to be called *burning glasses.* If you place a piece of paper at the focus of the lens, and look at it, before the heat of the converged rays has had time to set fire to it, you will see a small and very bright image of the sun.

The sun, however, is not the only object whose image may be obtained by means of such a lens. If you will hold a lighted candle on one side of the lens, and a sheet of paper on the other, by moving the paper back and forth, until the proper point is reached, you will obtain an image of the candle. (See Fig. 10.) This image will be turned upside down, or inverted, and it will be smaller than the candle, if the screen is nearer to the lens than the candle, and larger, if the candle is nearer the lens. The course of rays passing through a concave lens is shown in Fig. 11.

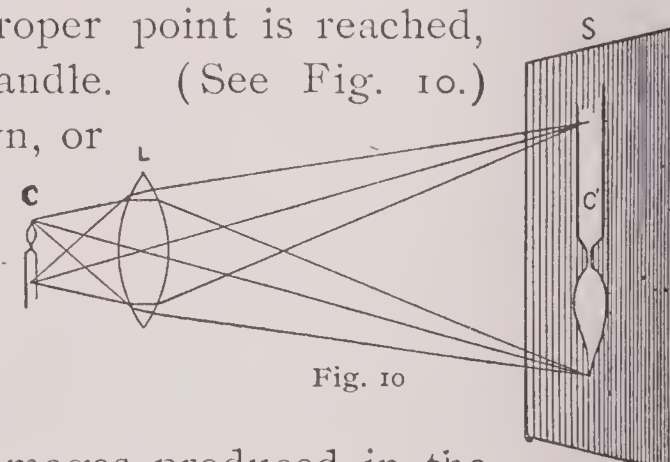


Fig. 10

The images produced in the way that has just been described are real images, because they are actually formed on screens, but lenses also produce virtual, or imaginary, images. If you take a convex lens, of the kind we have been talking about, and hold it close to some small object, on looking through the lens, you will see an enlarged image of the object; but, on trying to produce it on a screen, you will find that the image is imaginary. This imaginary image will not be inverted, like that formed on the screen. When a lens is used in this way, it is called a *magnifying glass* or *simple microscope.* The term microscope is applied to instruments used for viewing small objects.

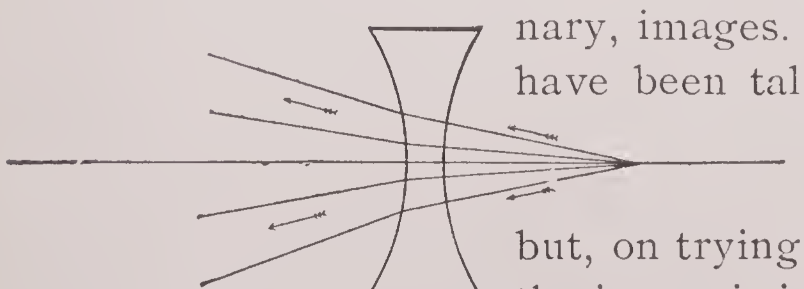


Fig. 11

Some Optical Instruments

By optical instruments are meant those instruments, in the use of which light plays an important part, such as the photographic camera, the microscope, the telescope, the magic lantern, spectacles, and the eye itself. In all of those just mentioned lenses are employed to form images.

The photographic camera (Fig. 12) consists essentially of a box, B, that has a lens, L, in one side. The side, G, opposite the lens is usually made movable, so that it can be drawn closer to the lens, or removed further from it, as desired. When the lens is uncovered, light enters through it and strikes upon the opposite side. By adjusting this side, which is commonly called the "back," an image of the objects in front of the lens will be produced. This image, like that obtained with the candle and the screen, is inverted, and it is formed in the same way. The only use of the box of the camera is to exclude all light, except that which comes through the lens.

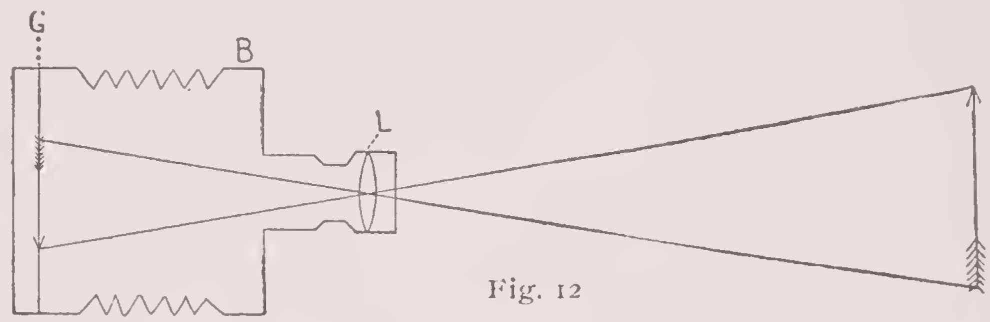


Fig. 12

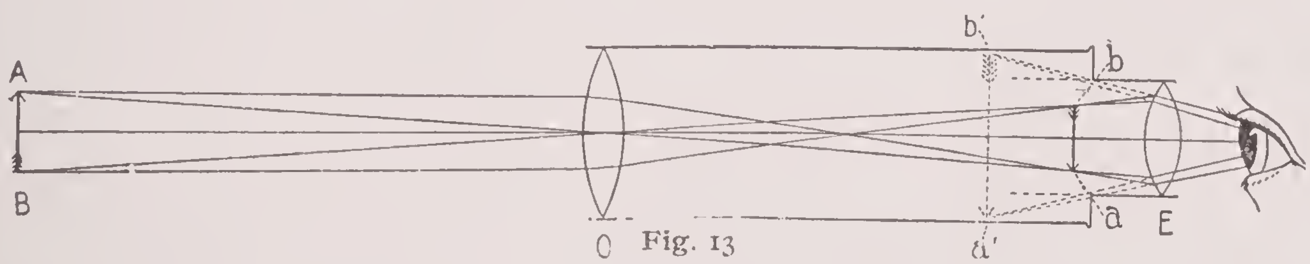


Fig. 13

A telescope (see Fig. 13) is an instrument used for viewing distant objects. In its simplest form it consists of a tube provided at one end with a large lens, O, for forming an image of the distant object, and at the other with a smaller lens, E, for magnifying the images formed by the large lens. The large lens, which is turned toward the object, is called the *objective*, and the small lens is called the *eyepiece*.

Microscopes are of two kinds, simple and compound. The simple microscope, as has already been stated, consists of a single convex lens. A compound microscope (see Fig. 14) resembles a telescope in having an objective and an eyepiece, but the objective of a microscope is a small lens adapted for use with very small objects, and it not only forms an image, but

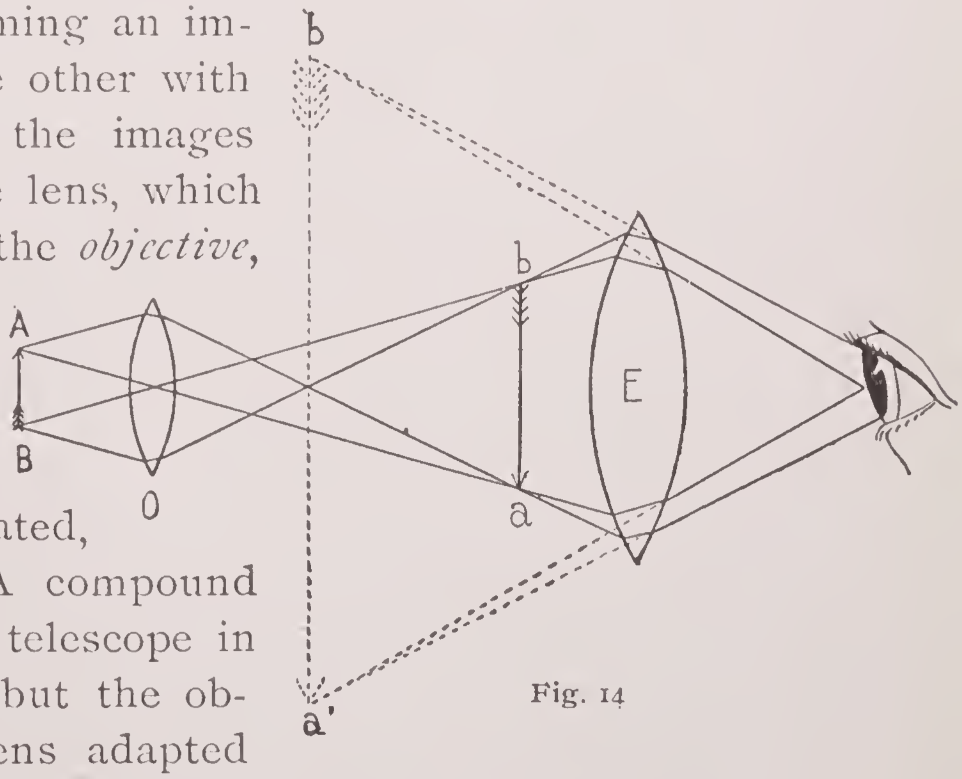


Fig. 14

also magnifies it. The eyepiece in a microscope acts in the same way as the eyepiece in a telescope.

A magic lantern (Fig. 15) consists of a device for producing a strong light, a reflector, and a tube containing a convex lens. When a picture on glass, or other transparent material, is placed between the light and the lens, and the reflector is so placed that it will throw the light through the picture, an enlarged image of the picture will be formed, on a screen placed at a proper distance in front of the lens.

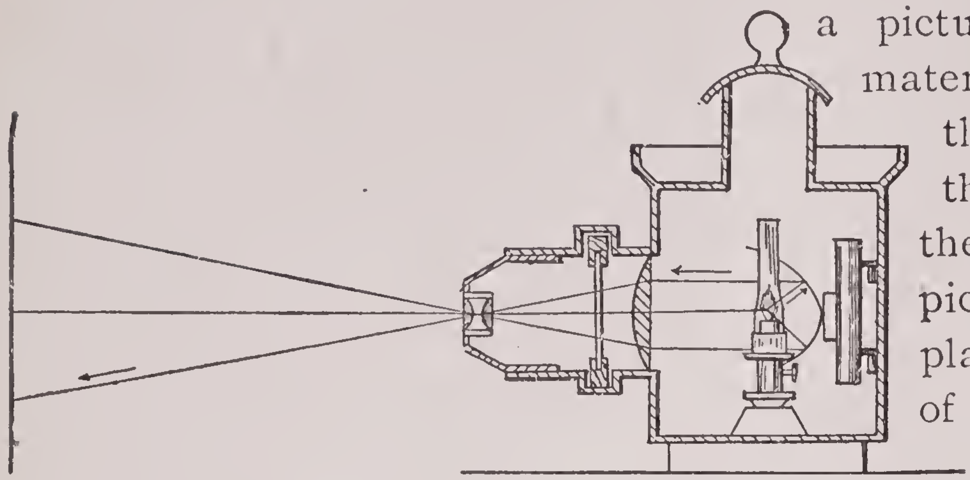


Fig. 15

The eye (Fig. 16) is a most interesting optical instrument, and in many ways it resembles a photographic camera. In front it has an opening called the pupil, through which light is admitted, and this is so constructed that it can be enlarged in weak light, or contracted in strong light by means of the iris, X. Behind the pupil lies a lens, L, that forms an image upon the back part of the eye, R, that is called the retina. The back part of the eye cannot be made to approach the lens and withdraw from it, like the back of a photographic camera, in order to form images of objects at different distances, but we know from experience that the eye adjusts itself to different distances almost instantly. This adjustment is accomplished by a change in the lens. The lens in the eye is not a hard, unyielding body, like the glass lens in a camera, but is a soft, yielding substance, that can be made flatter or more curved by a very slight increase or decrease of the pressure on it. For the formation of clear images of distant objects the lens must be flattened somewhat, while for those very near its curvature is increased. These changes are brought about by tiny muscles within the eye, which act so quickly and so easily that we are entirely unconscious of their action.

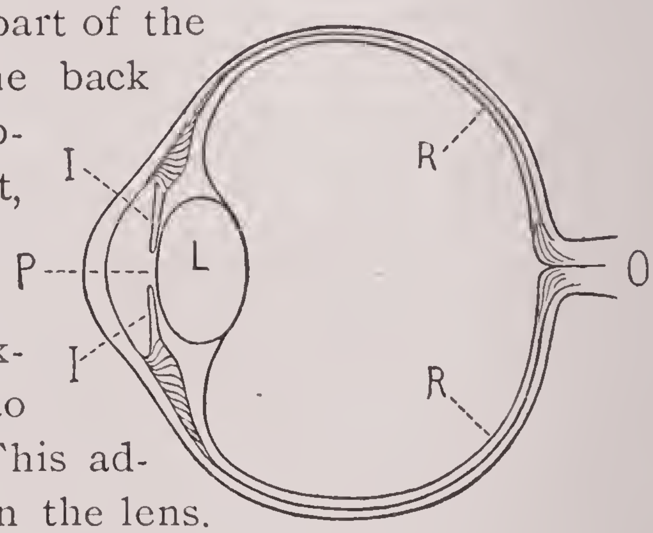


Fig. 16

The Rainbow and the Spectrum

As often as you have seen a rainbow, it may never have occurred to you, that you have to stand in a certain position in order to see it, and you probably cannot tell how it is produced. Of course, you know that the rainbow cannot be seen, unless the sun is shining and

there are little drops of water in the air. The drops need not be raindrops, for rainbows can be seen in the mist at Niagara Falls, whenever the sun is shining, and you may produce a small rainbow with a hose. All that is necessary, is to stand with your back to the sun and throw the water into the air in front of you, in the form of spray. The light from the sun enters the small drops of water, is reflected inside the drops, and comes back to your eyes, but instead of white light you now see red, orange, yellow, green, blue, indigo, and violet. These colors are known as the *seven colors of the spectrum.*

Drops of water are not the only means whereby white light may be broken up into these seven colors. If sunlight is allowed to pass through a triangular prism, such as that already described, the same thing is observed. And, when the position of the different colors is noted, they will be found as they appear in Fig. 17, the violet being refracted more than the others, and the red least of all. From the behavior of white light, when passed through a prism, we conclude that it is a mixture of colors that are always present, but cannot be distinguished by the eye, because they all reach it together. This view is strengthened by the fact, that by placing a second prism, in the reverse position beyond the first, we can bring the separate colors together again and reproduce white light. Other experiments, too complicated for description here, have proved that the different colors of the spectrum are produced by light waves having different rates of vibration, the violet rays having the highest rate and the red rays the lowest. Color in light is, therefore, closely related to pitch in sound. In luminous bodies, like the sun, the ether waves produced have many different rates of vibration, and they have wave lengths that are correspondingly different. These waves are all transmitted through the ether together, but, when they pass through a prism, the waves of different lengths are separated, because they are not refracted to the same extent.

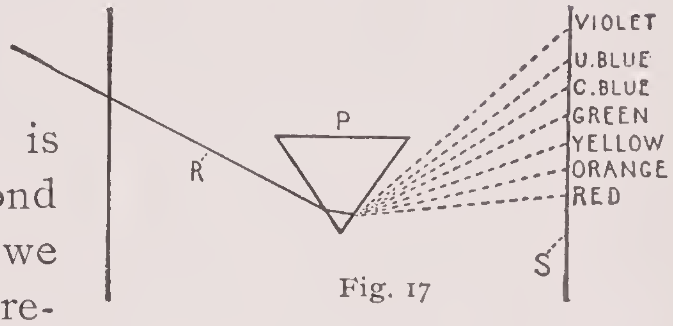


Fig. 17

Besides the waves that produce the colors shown in the spectrum, there are other waves of ether sent to us from the sun, some of them having more rapid vibrations, than the violet rays, and some slower vibrations, than the red rays. Our eyes are not so constructed that these rays have any effect upon them, however; hence such rays are called *invisible rays.*

Color in Bodies

When we are in a dark place all objects look black. In pure red light, they would look red or black. The color of an object always

depends upon the color of the light to which it is exposed. In white light all colors are possible, because it is composed of all the different colors. When white light falls on an object, it may be either reflected or absorbed. Generally, part of it is reflected and part absorbed. Different substances have different capacities for absorption, some absorbing more of one color, and others more of another. When a body readily absorbs red, it will appear green; when it absorbs green more than any other color, it will appear red. Those bodies, that absorb yellow most easily, appear blue, and *vice versâ*. Bodies that reflect all the colors appear white, and those that absorb all the colors are black. Colors related to each other in the way that red is to green, and yellow to blue, are called *complementary* colors, because when they strike the eye at the same time they produce the sensation of white.

Color.—What is termed the color-sense is the power or ability to distinguish kinds or varieties of light and their distinctive tints. We owe the faculty of doing this to the structure of the eye and its elaborate connecting nerve machinery. The eye in man is specially sensitive to light, and the sensations we feel through it enable us to distinguish the different colors. Over 1,000 monochromatic tints are said to be distinguishable by the retina of the eye, though these numerous tints are, in the main, merely blendings or combinations of the three primary color-sensations, the sense of red, of green, and of violet. Each of these colors, it has been demonstrated, is produced by light of a varying wave length, while white light is only light in which the primary colors are combined in proper proportion. Colored light, on the other hand, as Newton proved, may be produced from white light in one of three ways: First, by refraction in a prism or lens, as observed in the rainbow; second, by diffraction, as in the blue color of the sky, or in the tints seen in mother-of-pearl; and third, by absorption, as in the red color of a brick wall, or in the green of grass,—the white light which falls upon the wall being wholly absorbed, save by the red, and all that falls upon the grass being absorbed, except the green. In art, color means that combination or modification of tints which is specially suited to produce a particular or desired effect in painting; in music, the term denotes a particular interpretation which illustrates the physical analogy between sound and color.

Black.—Is the absence of color, as cold is the absence of heat. It may be produced by the mixture of unequal proportions of the three primary colors. In clothing it indicates mourning; in blazonry, constancy, prudence, and wisdom. Blackened surfaces absorb heat readily. For this reason dark clothing is warmer than white or light-colored.

Spectrum.— The image formed by refracted light, caused by passing a ray of sunlight through a prism, and displaying the seven primary colors as seen in the rainbow. See Light.

Stars, The, How They Are Counted.— By means of the telescope and photography. The Astronomer-Royal for Ireland, Sir Robert S. Ball, in one of his lectures mentioned a photograph which had been obtained by Mr. Isaac Roberts representing a small part of the constellation of the Swan. The picture is about as large as the page of a copy-book, and it is so crowded with stars that it would puzzle most people to count them; but they have been counted by a patient person, and the number is about 16,000. Many of these stars are too faint ever to be seen in the greatest of telescopes yet erected. Attempts are now being made to obtain a number of similar photographs which shall cover the whole extent of the heavens. The task is indeed an immense one. Assuming the plates used to be the same size as that above mentioned, it would require at least 10,000 of them to represent the entire sky. The counting of stars by the telescope was first reduced to a system by the Herschels, who introduced "star-gauges," which were simply a calculation by averages. A telescope of 18 in. aperture, 20 ft. focus, and a magnifying power of 180, giving a field of view 15 in. in diameter, was used for the purpose. The process consisted in directing this instrument to a part of the sky and counting the stars in the field. This, repeated hundreds of times, gave a fair idea of the average number of stars in a circle of 15 in. diameter in all parts of the sky. From this as a basis it is possible to reckon the number of stars in any known area.

ELECTRICITY AND MAGNETISM

Perhaps you have noticed, that if you pass a hard rubber comb through your hair, in frosty weather, a crackling sound is produced, and the strands of hair show a tendency to stick to the comb. You may have observed, also, that, after being drawn through your hair a few times, the comb has the property of attracting small, light particles, such as scraps of paper or chaff. This attractive property is due to the fact, that the comb has become *electrified*, or *charged with electricity*, by friction against your hair. There are many other substances, besides rubber, that may be electrified by friction. For example, a stick of sealing wax rubbed with flannel, or a rod of glass rubbed with silk will show attractive properties, similar to those manifested by the rubber comb; and, by experimenting with these objects, you may learn a number of facts about electricity.

The following experiments will be found interesting, as well as instructive. Electrify a stick of sealing wax, by rubbing it briskly with a piece of warm flannel, and then bring it near a small ball of elder pith, suspended by a silk thread. The pith ball will at once be attracted to the sealing wax, and, if the wax be brought close enough, the ball will adhere to it for a few moments, and will then fly away from it. Instead of being drawn toward the sealing wax, the pith ball will now be repelled by it. Electrify a glass rod, by drying it thoroughly and then rubbing it with silk. Bring the glass near the pith ball, which will be attracted by the glass, as it was, at first, by the sealing wax, but, if allowed to come into contact with the rod, the ball will adhere to it, for a few moments, and will then fly away, just as it did from the sealing wax. Now, bring the stick of sealing wax near again and the pith ball will be attached, as it was at first, but if it touches the wax it will again adhere for a moment and then drop off. By bringing the sealing wax and glass alternately into contact with the pith ball, you will find, that when it is repelled by one, it is attracted by the other, and that, after it has been in contact with either for a few moments, it is no longer attracted by it.

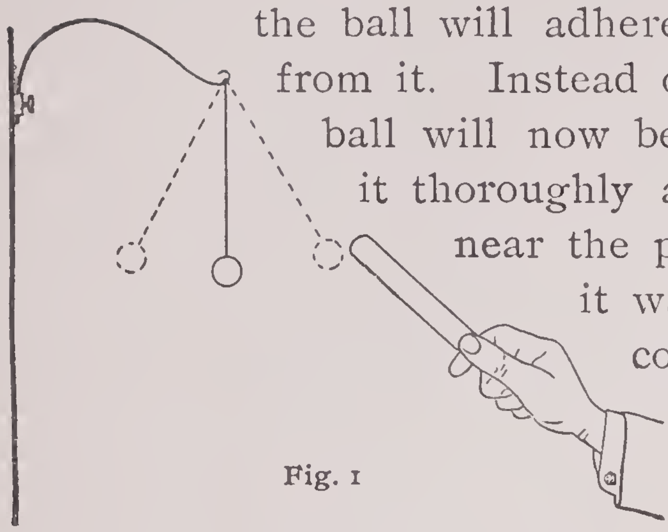


Fig. 1

From these experiments you will see that the charges upon the glass and the sealing wax are not the same, and, to distinguish the two kinds of electricity, the glass is said to be charged with *positive* or *vitreous electricity*, while the charge on the sealing wax is called *negative*, or *resinous electricity*.

Now, when the pith ball was touched with the sealing wax, it became charged with negative electricity, and was then no longer attracted by the wax, but was repelled by it and attracted by the glass. On the other hand, when the ball had been charged with positive electricity, it was repelled by the glass and attracted by the wax. We conclude from these facts that *bodies charged with the same kind of electricity repel each other, while bodies charged with opposite kinds of electricity attract each other.*

If two bodies, charged with opposite kinds of electricity, are brought together and allowed to remain in contact, for some time, the two charges disappear, one appearing to neutralize the other. From this, we may suppose, that any body, that is not electrified, contains both kinds of electricity, in equal amounts. Accordingly, when we rub a piece of glass with silk, we do not create electricity, but simply separate the two kinds, so that the positive kind adheres to the glass, and the negative kind remains behind, on the silk. In like manner, when we electrify sealing wax with flannel, the negative electricity re-

mains in the sealing wax, and the flannel becomes charged with the positive. Whenever a body is electrified by friction, both kinds of electricity are produced; it is impossible to produce one kind without the other.

If a part of the glass rod, or piece of sealing wax, is rubbed, only that part becomes electrified, as may be shown by trying to attract a pith ball, with the part that has not been rubbed. But, if the charged part of the sealing wax is brought into contact with a metal rod resting on a glass tumbler, the rod becomes charged, not only at the point of contact, but all over its surface. Substances over which electricity flows readily, as it does over metals, are called *conductors* of electricity, and substances like glass and sealing wax, over which electricity does not flow readily, are called *non-conductors*, or *insulators*. In the former class are included water, the human body, and the earth; in the latter, rubber, porcelain, most resins, and dry air.

You have already been told that bodies charged with opposite kinds of electricity attract each other, and bodies charged with the same kind repel each other. Let us now seek to discern, why it is that bodies charged with either kind of electricity attract small light objects, like pith balls, when they are not charged with electricity. It has been stated, that all uncharged bodies are supposed to have both kinds of electricity present in them, in equal amounts. Now, when an uncharged body is brought near a charged body, there is a tendency for the two kinds of electricity in the uncharged body to separate, the kind opposite in character, to that on the charged body, being attracted toward the charged body, and the other kind being repelled. Thus, if a stick of sealing wax, charged with negative electricity, is brought near a ball of pith, the positive electricity in the ball is attracted to the side nearest the sealing wax, and the negative electricity is repelled to the farther side. (See Fig. 2.) As the positive electricity on the pith is nearer to the sealing wax than the negative, its attraction for the negative charge, on the sealing wax, is stronger than the repulsion between the negative electricities of the two objects, and consequently, the ball is attracted to the sealing wax. If the charged sealing wax is brought near an insulated conductor, that is, a conductor supported on some non-conducting substance, such as glass, silk, or rubber, over which electricity will not flow, there is a much more complete separation of the two kinds of electricity on the conductor than there was on the pith ball. If the charged sealing wax is brought near one end of the metal rod, the charge of negative electricity upon the sealing wax will attract the positive electricity on the metal, to that end, and will repel the negative electricity to the other

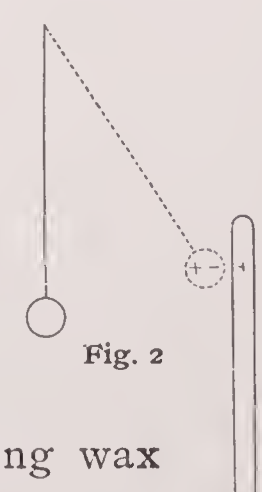


Fig. 2

end. If a pith ball suspended by a silk thread is brought near either end of the metal rod, while the charged sealing wax is near one end of it, the pith ball will be attracted toward the rod; but, if brought near the middle of the rod, it will not be attracted. This shows that the rod becomes electrified, only in the part nearest to the charged body and in the part farthest from it. At the middle, between these parts, the two kinds of electricity neutralize each other.

By taking two conductors, and placing them end to end, we form what is, practically, a single conductor, but it has the advantage of being easily separated into two parts. When a charged body is brought near one end of a conductor, made up of two separate parts, a charge of one kind is attracted to the nearer part of the conductor, and a charge of the opposite kind is repelled to the farther part. By now separating the two parts of the conductor, we find that one of the ends, that were in contact, is charged with positive and the other with negative electricity.

The separation of the two kinds of electricity, upon a conductor, by means of a charge upon another body, which is not allowed to come into contact with the conductor, is called *induction*, and two charges of electricity, produced in this way, are known as *induced* charges. The charge, by means of which the separation is brought about, is called the *initial* or *inducing* charge.

Another way, in which a charge of electricity may be induced upon a conductor, is to have one end of the conductor connected with the earth by means of some conducting material, and then to bring a charged body near the other end. A charge, opposite in character to the initial charge, is attracted to the end of the conductor that is near the charged body, and the electricity of the opposite kind is repelled, through the conductor to the earth. By breaking the connection with the earth, while the charged body is near the conductor, a charge is obtained upon the conductor, that is opposite in character to the initial charge. This method of charging conductors, by induction, is practically the same as the one first described, for the earth is a conductor of electricity, and corresponds to the more distant part of the two-piece conductor.

An instrument, known as the *electrophorus*, which is especially designed for the production of electric charges by induction in the manner just described, is shown in Fig. 3. This instrument consists of a brass plate, A, on an insulating handle of glass, C, and a disk of sealing wax, B, fitted into a brass dish, D, whose edges rise somewhat higher than the surface of the wax. In using the electrophorus the brass dish, or *sole*, is placed upon some support that will conduct electricity, and the sealing wax disk is then rubbed vigorously with a piece of flannel, or

catskin, which electrifies the sealing wax, with negative electricity. The brass plate, A, is then taken by the glass handle C, and brought close to the charged sealing wax. The charge of negative electricity on the wax attracts a charge of positive electricity to the under surface of the plate, A, and repels a negative charge to its upper surface. If the charged plate is now brought into contact with the edge of the brass dish, D, the negative charge, on the back of the plate, flows away, through the legs of the dish, to the earth, but the positive charge remains on the under surface, where it is *bound*, by the attraction of the negative charge on the disk of sealing wax. If the brass plate, A, is now removed, it will be found to be charged with positive electricity.

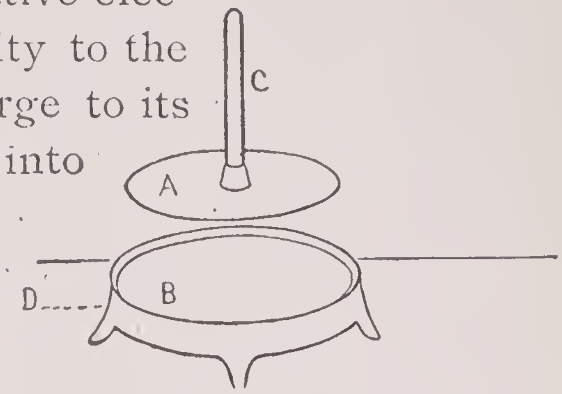


Fig. 3

The negative charge upon the sealing wax is not reduced or diminished by its action in charging the brass plate, and it is possible to charge the plate an indefinite number of times by means of one charge on the sealing wax.

The charges of electricity, produced in any of the ways that have been described, are necessarily small, and the disturbance produced, when they are destroyed by bringing oppositely charged conductors together, is very slight, merely a little snapping noise and, perhaps, a small spark, that seems to leap from the positively charged conductor to the negatively charged one, when they come very close together. By the use of electrical machines of various kinds, in some of which the electricity is produced by friction, and in others by induction, conductors may be charged with much larger quantities of electricity, and the disturbance produced by their discharge is greatly increased. The noise produced is louder, and the spark is much brighter, and leaps from one conductor to the other, while they are much farther apart. It is possible to produce still larger charges of electricity upon conductors, if they are arranged so as to form what are called *condensers*. One of the commonest forms of condenser is the *Leyden jar*, which is so named because it was invented at Leyden, in Holland. (Fig. 4.) This is a glass jar, G, upon the outside of which is fastened a coating of tin foil, T, that covers the bottom of the jar and extends two-thirds of the way up the sides. Inside the jar there is a similar coating of tin foil, T^1, and through the top of the jar, S, which is usually made of wood, extends a metal rod, R. On the upper end of the rod, there is a metal ball, and, at the lower end, is attached a chain, C, which runs down to the bottom of the jar, and rests upon the inner tin foil coating.

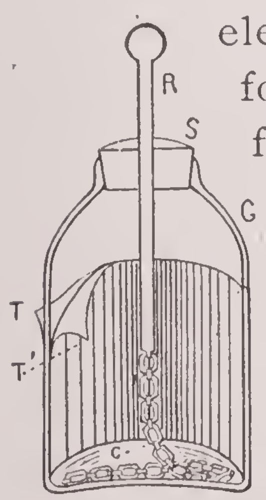


Fig. 4

In using the Leyden jar, the ball on the metal rod that runs through the top of the jar is connected with an electrical machine, and the jar is supported upon some conducting material, through which electricity may be conveyed from the outer coating of tin foil to the earth. If the inner coating of tin foil is now charged with positive electricity, by means of the electrical machine, it induces, upon the outer coating of foil, a charge of negative electricity, which is bound by the attraction of the positive charge on the inside of the jar. At the same time, the positive electricity, on the outer coating of foil, is repelled, through the conducting support, to the earth.

The charge that can be communicated to the coating of the foil, inside the Leyden jar, is greatly increased by the presence of a charge of the opposite kind of electricity, on the coating on the outside of the jar. Each of these charges attracts the other, through the glass of the jar, and serves to bind or hold it. If either coating of foil is removed, the charge on the other coating tends to fly off the tin foil, and will immediately do so, if a conductor is brought near. It is because the attractive effects of the initial charge, inside the jar, and of the induced charge outside the jar, make it possible to communicate, to each coating of foil, a larger charge than it could otherwise be made to receive, that a Leyden jar is called a condenser.

When a Leyden jar is disconnected from the electrical machine, two opposite charges of electricity are present on it, one inside and the other on the outside. If the two coats of tin foil are now connected, by means of a conductor, they will at once neutralize each other, and the jar will be discharged. A jar may be discharged, by simply taking hold of the tin foil on the outside of the jar, with one hand, and touching the metal rod, running through the top of the jar, with the other. If you do this, there will be a sudden flow of electricity through your body, your muscles will give a sudden jerk, and you will feel a peculiar tingling sensation. In other words, you will have received a *shock*.

It is not necessary, for the hand that does not grasp the jar, actually to touch the rod that runs through the top. If the hand is brought toward the rod, rather slowly, you will see a spark leap across the space, between the rod and your hand, while your hand is still some distance from the rod. The greater the distance, across which the spark leaps, the brighter will be the spark, and the stronger the shock produced. This distance is sometimes spoken of as the *length of the spark*, and it indicates the size of the charges on the tin foil coatings of the jar.

It may seem difficult to believe, that the tiny spark and weak snapping noise that are produced when a Leyden jar is discharged, are, in many respects, the same as lightning and thunder, but it is nevertheless true. This was proved by Benjamin Franklin, about the middle of the 18th century, in the following way. One afternoon, when a thunder shower was approaching, he sent up a kite, to the string of which he fastened a large metal key; and to the key, a ribbon of non-conducting silk, which he held in his hand. When the rain had been falling long enough to wet the string thoroughly, it became a good conductor of electricity, and Franklin found that the key had become charged with electricity transmitted from the clouds, along the wet kite string. The non-conducting silk ribbon, that formed the continuation of the kite string, from the key to his hand, was employed to prevent him from receiving shocks from the passage of the electricity, through his body, to the earth.

Up to this point, your attention has been directed to charges of electricity. You have been told how they may be produced, what some of their leading properties are, and what effects they produce, when they are discharged. The subject that will now be explained to you is that of *electric currents.*

By an electric current, is meant a flow of electricity along a conductor. The flow of electricity, through your body, when you receive an electric shock, is a current, but it lasts only for an instant, and it is difficult to learn much about its nature. By the use of various devices, it is possible to produce currents, that will continue as long as we want them, so that we are enabled to study their properties quite thoroughly.

One of the oldest and simplest forms of apparatus, for producing electric currents, is that which is known as the *voltaic cell.* This form of apparatus may very easily be constructed. (See Fig. 5.) Pour some water into a glass jar, and add a little sulphuric acid. Now place in the water a strip of clean zinc and one of clean copper. Do not let the strips of metal touch in the water, but connect them outside the water by means of a piece of wire. When this has been done, a current of electricity will be set up along the wire and through the water between the two strips of zinc and copper. This current is said to flow along the wire from the copper, which is called the *positive pole* of the cell, to the zinc, which is called the *negative pole.* In the liquid in the cell (*i. e.*, the jar), the current travels from the zinc to the copper, thus completing what is called the *electric circuit.* Whenever the circuit is broken, that is, whenever there is a gap made in the wire connecting the poles, or anything else is

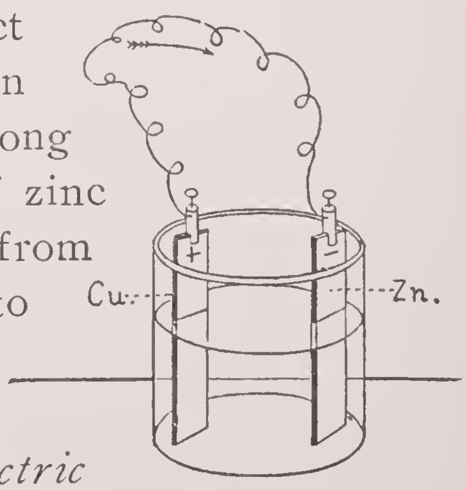


Fig. 5

done to destroy the completeness of the conducting path, along which the current travels, the current ceases; consequently, when it is desirable to stop the current, all that is necessary is to cut the wire connecting the two strips of copper and zinc.

The production of a current of electricity, by means of an apparatus of this sort, depends upon the chemical action of the acid in the water upon the strip of zinc. As long as the acid continues to act upon the zinc, a current is produced, and when the acid ceases to act upon the zinc, the current ceases to flow. If the zinc is clean, the chemical action of the acid ceases, whenever the circuit is broken, and consequently, when the cell is not being used to produce a current, the zinc is not destroyed by the acid. But if the zinc is not clean, small electric currents are set up, within the liquid, between the zinc and the impurities on its surface, and around the points where these impurities lie the acid acts upon the zinc and dissolves it. This action of the acid upon the zinc, when the circuit is broken, is known as *local action*, and it is very desirable to prevent it, as far as possible. For this purpose the zinc is often rubbed with mercury, which soaks into the zinc and forms a film on its surface, upon which the impurities float. This treatment of the zinc is known as *amalgamation*, and it serves to prevent almost all the local action, due to impurities of the zinc.

Many other substances, besides zinc and copper, have been found capable of yielding an electric current, when placed in a suitable liquid, and many other fluids, besides water that contains a little sulphuric acid, have been employed to act upon the zinc and copper, or the substances used in their stead. Numerous cells of different kinds have, therefore, been devised, but, in all of them, the current is produced by chemical action. Most of them contain a liquid of some sort, which is called the *exciting fluid*, and two solid substances, which are called the *elements* of the cell. One of these *elements* is always much more susceptible to the chemical action of the exciting fluid, than the other, and this one is known as the *positive* element. The other element, upon which the exciting fluid may have no action, is called the *negative* element. In cells, in which the elements are zinc and copper, the zinc is always the positive element. This may seem strange to you, for you have already learned, that the zinc is the *negative pole* of the cell, but, to avoid confusion, you must fix well in your mind the fact, that the zinc is not the *positive element* of a voltaic cell, but its *negative pole*, and that the copper, which forms the *negative element* is the *positive pole* of the cell. The currents, produced by the various forms of voltaic cells, vary considerably in strength, but none of them are very strong. In order to obtain a stronger current, a

number of cells must be used together. Such a collection of cells forms a voltaic battery, and, in some instances, as many as fifty thousand cells have been used in a single battery.

Some of the effects produced by electric currents have already been mentioned, in the preceding pages of this volume. In the article on water, you learned that an electric current has the property of decomposing water into the elementary gases, oxygen and hydrogen. This is a chemical effect of the electric current. But water is not the only substance that is decomposed by electricity; almost all chemical compounds may be decomposed, by the passage of a current through them, provided a current of sufficient strength is used.

Another effect of the current, that has previously been mentioned, is its heating effect. It has been found that the passage of an electric current, through any body, is always productive of a certain amount of heat. The amount of heat produced depends upon the strength of the current of electricity, and the resistance to its passage that is offered by the body through which it travels. This amount is increased by increasing either the strength of the current or the resistance of the conductor along which it travels. You have already been told, that some substances allow electricity to pass over them very readily, and are therefore called conductors, while substances, through which electricity does not flow readily, are known as *insulators* or *non-conductors*. No substance is a perfect non-conductor, for electricity can be made to pass through any substance, if the current is sufficiently powerful. Neither is any substance a perfect conductor, for all substances offers some resistance to the passage of an electric current. Those substances that are ordinarily considered good conductors offer varying degrees of resistance to electric currents. For example, a copper wire offers less resistance than an iron wire of the same length and diameter.

The resistance of a body depends not only upon its material, but also upon its length and size. In conductors of the same material, the resistance is directly proportional to the length of the conductor, and inversely proportional to the square of its diameter. This is not surprising, for an electric current bears a strong resemblance to a current of water, in many of its properties, and you know that it is harder to force water through long, narrow pipes, than through short, wide ones.

From what has been stated about resistance, you may see that a current will produce more heat, in passing through a long, fine wire, than through a shorter and thicker one, and that, of two conductors of the same length and size, but of different material, one may be heated much more by a current than will another.

A third effect of the electric current, which has not previously been mentioned, is its magnetizing effect. It is upon this, that some of the most important effects of electricity depend.

By coiling a wire around a bar of iron or steel, and then sending an electric current through it, the piece of iron, or steel, is made to show magnetic properties. By this is meant, as you doubtless know, that the iron will now attract other pieces of iron, or steel, to it. The strength of this attraction depends upon the strength of the current, and upon the number of turns of wire around the bar. By increasing either the strength of the current, or the number of turns in the coil of wire, around the bar of iron, the strength of its magnetic attraction is increased. When the current is stopped, the magnetic properties of the iron disappear almost completely. A magnet, that depends upon a current of electricity for its magnetic power, is called an *electro-magnet*.

Besides electro-magnets, there are others, which are called *permanent magnets*. Electro-magnets are composed of soft iron, the softer the better, and, as soon as the current of electricity ceases to flow around them, their magnetic properties disappear. Permanent magnets, on the contrary, are made of steel, and their magnetism is independent of the action of a current of electricity. No coil of wire is wound around them, and no current is employed to maintain their magnetic properties. A piece of steel may be made to become a permanent magnet, by passing a current of electricity, for a considerable time, through a coil of wire wound around it, or by allowing a piece of steel to remain for some time in contact with a strong magnet. When a current of electricity passes through a coil of wire, wound around a bar of steel, it takes longer to magnetize the steel than it would to magnetize iron, but, when the current ceases, the magnetism does not all disappear from the steel. A portion of it remains, and the steel becomes permanently magnetic.

If a thin bar of steel is magnetized, and is then suspended, by its middle, so that it can swing freely, it will be found that one end tends to point toward the north, and the other toward the south. Whenever the bar is swung out of this position, it swings back to it, and if the north end is turned entirely around to the south, it does not remain, but swings back to its former position. This shows that there is a difference in the magnetism at the two ends of the magnet. To indicate this difference, the north-seeking end of a magnet is called the *positive*, or +, *pole* of the magnet, and the south-seeking end is known as the *negative*, or —, *pole*.

By suspending two bar magnets, in the manner described, it can be shown that the positive and negative poles of the magnets act like

positive and negative charges of electricity. Poles of the same kind repel, and poles of opposite kinds attract, each other.

Permanent magnets are usually made in two forms, either straight or horseshoe shaped. A compass needle, as has been shown, is an example of a straight magnet. The horseshoe variety which has a little bar of iron, called the keeper, laid across the poles, is a common toy. Electro-magnets are seldom seen, except in electrical instruments or machinery.

Besides the electro-magnet, and the permanent magnet of magnetized steel, there is another kind known as the *natural magnet*, or *lodestone*. This kind of magnet is a variety of iron ore, some forms of which have magnetic properties. Many startling stories were formerly told of the power of lodestones, but we now know that they were great exaggerations, and that no natural magnet ever found had one-hundredth part of the power of the large electro-magnets.

Having discussed some of the properties of charges of electricity, electric currents, and magnets, we may now take up the operation of some of the more important applications of electricity, such as the telegraph, the telephone, electric lights, electric railways, and the like.

The telegraph in its simplest form may be represented by the diagram in Fig. 6, in which B represents a battery, composed of a number

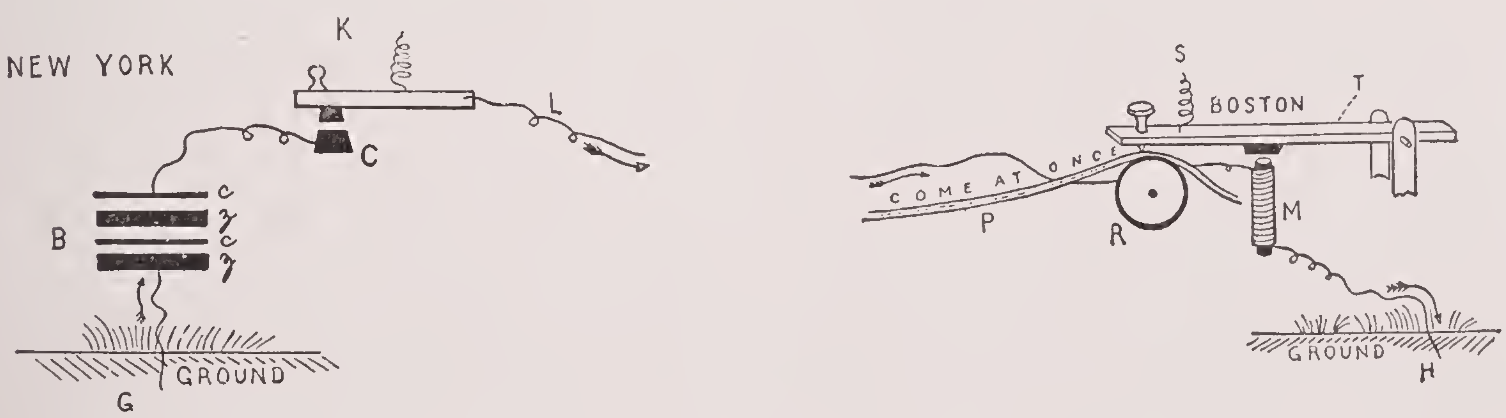


Fig. 6

of voltaic cells, K a telegraph *key*, L a line of wire, and S a *register*. One wire, from the battery, B, runs to a plate of metal, G, buried in the earth, which is known as a *ground*. The other wire, from the battery, goes to the piece of metal, C, over which is the key, K. From K, a wire runs to another station and is there connected with an electro-magnet, M, from which another wire goes, to another ground, H. Over the electro-magnet, M, is a pivoted box, T, on which is fastened a piece of iron that is so placed that the attraction of the electro-magnet, M, may draw it down into contact with the magnet. The bar, T, is supported by a spring, S, which keeps the piece of iron on the bar out of contact with the electro-magnet, when a current of electricity is not passing through the coils of the magnet. At the free end of the bar, T, is a

point that makes marks on a narrow strip of paper, P, which passes over a roller, R, under the point.

When the key, K, is in the position shown in the diagram, no current can flow through the wire, from the battery, B, and consequently the electro-magnet, M, is not excited, and the bar, T, remains suspended by the spring, S. If the key, K, is pressed down upon the metal, C, the wire, L, is connected with B, and, as the earth is a conductor, the circuit is completed. A current then flows through the line, L, down through the coils of the electro-magnet, M, and through the earth back to B. As soon as the current passes through the coils of M, the iron bar, that forms the core of the electro-magnet, becomes magnetic, and attracts the piece of iron on the bar, T. This causes the piece of iron to strike the core of the magnet with a sharp click, and, at the same time, causes the point at the end of the bar, T, to come into contact with the paper, P, which travels over the roller, R, beneath it. The point that strikes the paper carries ink, and makes a mark on the paper every time it strikes it. By keeping the key, K, down on the piece, C, or in other words, *closing the circuit*, for an instant only, a dot will be produced on the paper, P. By keeping the circuit closed for a longer time a dash will be formed on the paper. As the key, K, can be raised and lowered at will by the operator, it is evident that he can cause the point to make dots or dashes as he pleases. Various combinations of dots and dashes have been chosen to represent the letters of the alphabet, and by their use words may be spelled and sentences formed.

The telegraph, as described above, is what its name implies, an instrument for writing at a distance. That was the form in which the telegraph was first brought into general use, but as now employed it is not really a telegraph. The register, S, has been replaced by a *sounder*, shown in diagram in Fig. 7.

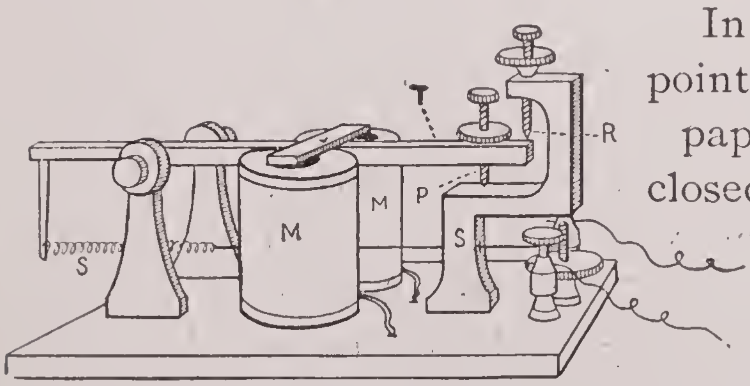


Fig. 7

In the sounder the bar, T, is not provided with a point for registering dots and dashes on a strip of paper, but is so arranged that when the circuit is closed and the magnet, M, excited, the bar, T, will be drawn down so that the point, P, will strike against the standard, S, and when the circuit is broken, or opened, the bar will move in the opposite direction and strike the point, R. The interval between the two clicks that are produced when the metal bar strikes the points, P and R, will indicate the length of time that the circuit was closed. A very short interval corresponds, of course, to a dot, and a longer interval to a dash, as made on the strip of paper used in the old form of instrument. Since

telegraph operators soon learn to recognize the length of the intervals between the clicks of the sounder, they can read the message from the sounds, and have no need for the paper.

In order to send messages in both directions over the same line, there must be both a key and a sounder at each end of the line, and if there are stations along the line, all the keys of the way stations must be closed, when a message is sent from one end of the line to the other.

In recent years improvements in the telegraph have been invented which make it possible to send messages over the wire in both directions at once, but these and several other improvements are too complicated to be easily understood.

The telephone is naturally associated with the telegraph, because the names and uses of the two instruments are similar; but in structure and operation they are quite different. The telephone, as invented by Professor Bell, which is the one that will be described, is shown in diagram in Fig. 8.

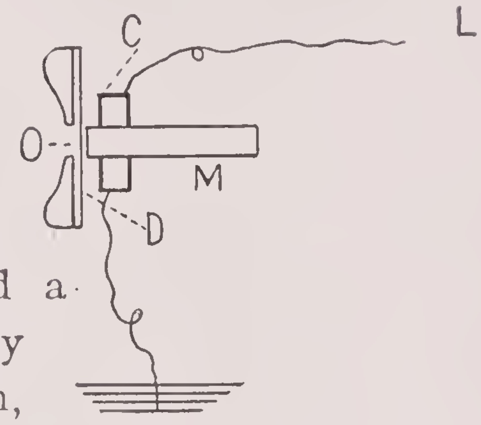


Fig. 8

In this kind of telephone the same form of instrument was used both for the *transmitter* and for the *receiver*. The transmitter is the instrument into which you speak, and the receiver is the one at which you listen. In constructing each of these instruments Professor Bell used a thin sheet of iron, D, a steel magnet, M, and a coil of very fine wire, C. From this coil, C, a wire ran to the earth, and another ran to the coil in the other instrument, from which a wire also ran to the ground, and the circuit was thus completed. No battery was required.

In using the Bell telephone, one speaker stood facing one of the instruments and spoke into the opening, O. The sound waves that issued from the speaker's lips struck the iron diaphragm, D, and caused it to vibrate. When it moved toward the magnet, M, it increased the strength of the magnet, and this caused a current of electricity to be set up in the coil of wire, C. When it swung back, the strength of the magnet was weakened, and a current, that was opposite in direction, was set up in the coil. These currents were transmitted to the coil of the receiving instrument, and, in passing through it, they caused the strength of the magnet to vary, as it did in the transmitting instrument. The variations in the strength of the magnet, in the receiving instrument, caused the iron diaphragm to be thrown into vibrations, similar to those caused in the transmitting instrument by the sounds of the speaker's voice, and the vibrations, so produced in the receiving instrument, gave rise to waves in the air that could be recognized as sounds similar to those of the speaker's voice.

In the other great applications of electricity, such as the driving of machinery, the propulsion of railway cars, and electric lighting, much stronger currents are required than can be readily produced by any of the methods that have been described in the preceding pages. The means by which these large currents are produced is a machine called a *dynamo*. The principle governing the construction and operation of the dynamo is illustrated in diagram in Fig. 9, in which N and S respectively represent positive and negative magnetic poles and A is a loop of wire so placed that it may be revolved between the poles. The ends of the loop terminate in two semicircular pieces of copper, P and R. When the loop of wire is revolved between the magnetic poles, a current of electricity is set up in it, which travels in one direction during half a revolution, and in the opposite direction during the other half. If the machine were so arranged that one end of the loop were always connected with the same end of the outside conductor, C, the current through C would be changing its direction, at every half revolution of the loop. A current of this sort is called an *alternating* current. In the diagram, however, the machine is arranged to produce a continuous current. Each of the semicircular pieces of copper, to which the ends of the loop are connected, comes into contact with the spring, B, during one half revolution, and with the spring, D, during the other half revolution of the loop. By this means the current is always made to flow from the machine, through the spring, B, for, when the current ceases to flow through the semicircle of copper at one end of the loop, that semicircle passes into contact with the spring, D, and the other semicircle, from which the current is about to flow, comes into contact with B. The semicircles of copper, at the ends of the loop, form what is called the *commutator* of the dynamo. This name is given them, because, by their use, the current is changed from an alternating to a continuous one. In a dynamo, such as is actually used to generate very strong currents of electricity, the single loop, A, is replaced by a great many loops, which are carefully insulated from each other, and are wound on an iron drum or core. These loops, or coils, together with the core on which they are wound, form the *armature* of the dynamo. Instead of semicircles of copper at the ends of each loop, the commutator now consists of smaller

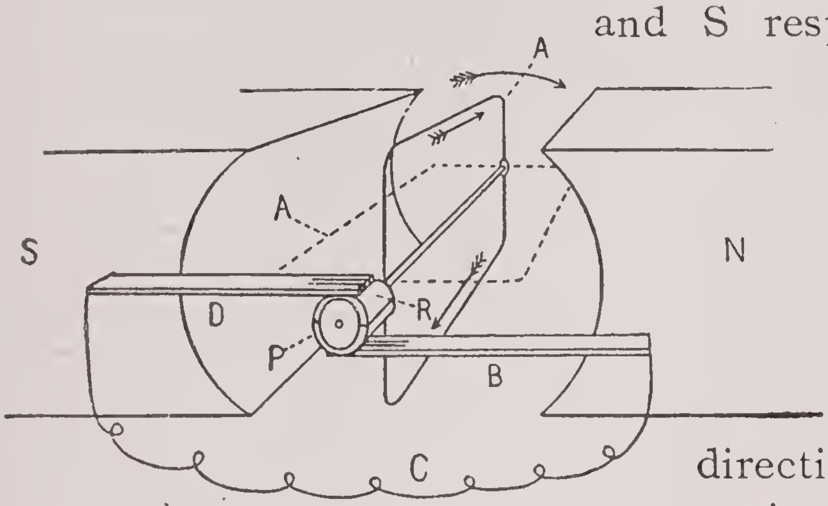


Fig. 9

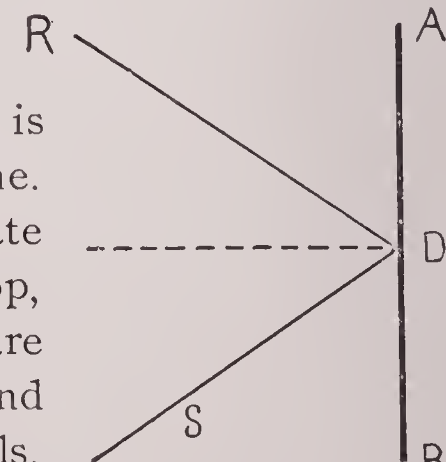


Fig. 10

pieces of copper arranged as shown in Fig. 10, for there are now too many loops for a whole semicircle to be placed at the end of each. The pieces of copper, in which the loops terminate, are carefully separated from each other, by non-conducting material, and they serve the same purpose that the semicircles did in the simple machine already described.

It is sometimes desirable to have an alternating current, instead of the continuous form, obtained from a dynamo, through the agency of a commutator. Dynamos designed to yield alternating currents have two insulated brass or copper rings, on the axis of the armature, in place of the commutator, and one set of ends of the loops on the armature is attached to one of these rings, and the other set to the other ring. The springs, or brushes, B and D, shown bearing on the commutator in Fig. 11 are so placed that one rests upon one ring, and one upon the other. By this means, an alternating current is sent through the outside conductor.

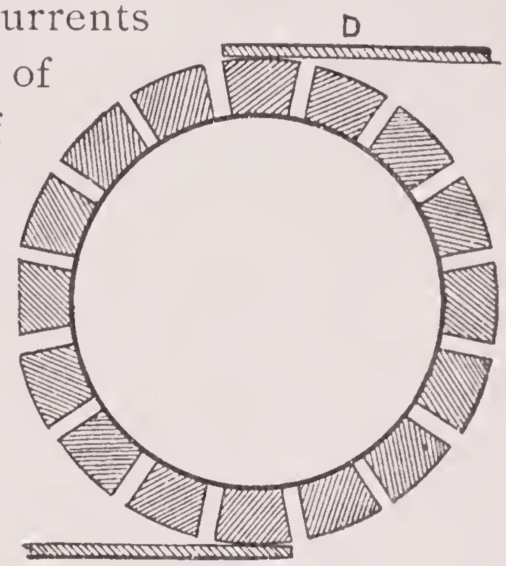


Fig. 11

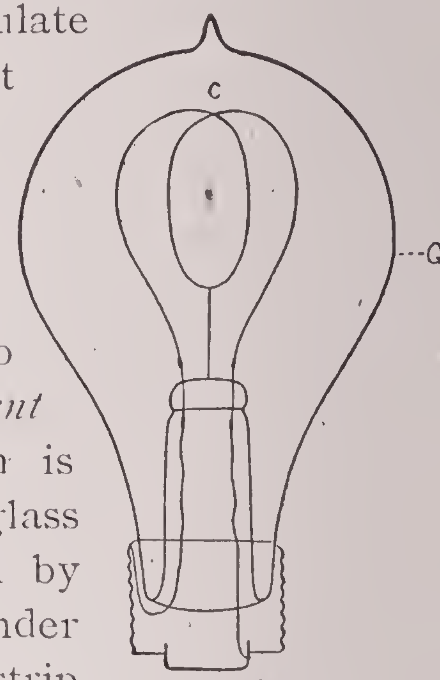
The strength of the current obtained from a dynamo depends upon the strength of the magnets, the number of coils, or loops, on the armature, and the speed at which the armature revolves.

A dynamo can be used to produce electric currents when its armature is made to revolve by mechanical energy, and, conversely, when currents are passed through the armature, the dynamo is made to revolve. When used in the latter way a dynamo is called a *motor*, and it can be employed to drive machinery. Any dynamo can be used as a motor, but it is customary to construct the machines that are to be used as motors somewhat differently from those that are to be used as generators of electric currents. Hence, the machines that are ordinarily called dynamos differ considerably in appearance from those that are called motors.

In driving machinery, or in propelling railway cars by means of electricity, a dynamo is required to produce the current, and a motor to convert the power of the current into motion. The advantage obtained by the use of electricity, for these purposes, is, that the dynamo may be situated in some convenient place, and the current may be transmitted, through wires, to the places where it is needed.

Most of the electric railways, now in use, have an overhead wire, which transmits a very strong current from a dynamo at the power house, and each car is provided with a motor. By means of a copper wheel, which rolls along on the overhead wire, and a wire which runs from it to the motor, the current is conveyed from the overhead wire to the motor on the car, and, from the motor, the current is trans-

mitted to the ground, through the wheels of the car. In this way a circuit is completed, and the current passes through the overhead wire to the car, thence, through the car motor and the car wheels to the ground, and through the ground back to the dynamo. The strength of the current that passes through the motor on the car is controlled by means of a device, called a *controller*, which is operated by the motorman on the car. By its use he can regulate the speed of the car, and can start or stop it at will.



Fig, 12

Of the other applications of electric currents to useful purposes, only the electric light will be considered here. Up to the present time, only two forms of electric lights have come into general use. These are known as the *incandescent* and the *arc* light. The former, Fig. 12, which is used chiefly for house lighting, consists of a glass bulb, G, from which the air has been exhausted by an air pump, and which is fitted with a very slender filament of carbon, C, formed by charring a thin strip of bamboo. This filament of carbon opposes high resistance to the passage of a current of electricity, and, consequently, when a current passes through it, the filament is heated white hot and gives off a bright light. The removal of the air from the bulb prevents the carbon from burning up, as it would do if oxygen were present.

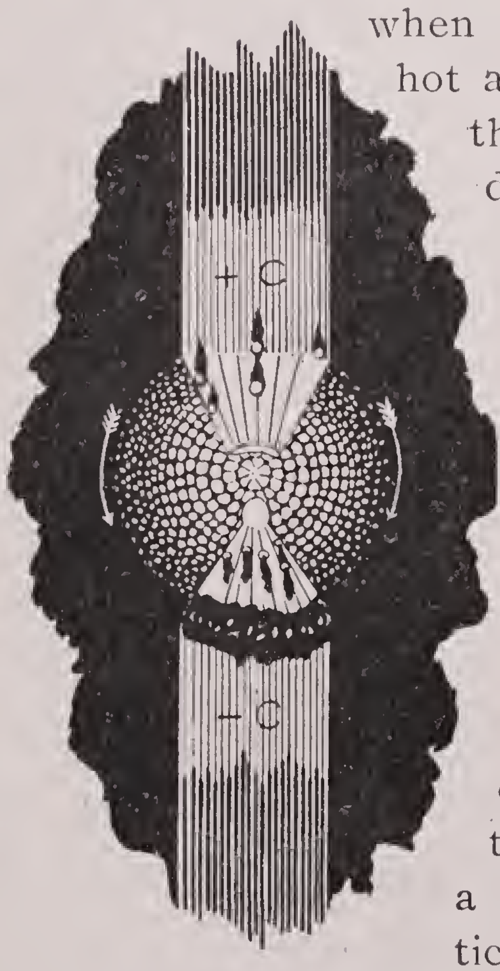


Fig. 13

In the arc light (Fig. 13) a current of electricity is made to leap across from the tip of one rod of carbon to the tip of another that is held a short distance from the first. In passing across, the current does not follow a straight path, but makes a curve, or arc, whence comes the name "arc light." In this form of light the carbons are not enclosed in a space from which air is excluded, consequently there is some destruction of the carbon. The light is due to the fact that the air between the tips of the carbon rods opposes a high degree of resistance to the current, so that the rods become intensely hot at their tips. The high degree of heat causes a slow burning of the carbon at the tips, and the small particles that burn are heated white hot before they are consumed, thus producing light.

In order to keep the light from an arc light uniform in strength, it is necessary to keep the tips of the carbon rods always the same distance apart. This is practically impossible, and, as a result, the arc

light does not produce light that is well adapted for reading or for other purposes that require constant use of the eyes. The light produced by the arc light is very powerful, however, and for that reason it is much used for street lighting.

Mr. Peter Cooper Hewitt has applied his mercury vapor interrupter and static converter to electric lighting. It produces a steady, pure light seven times brighter and much cheaper than the ordinary incandescent burner. The light has the effect of modifying the colors of some objects upon which it shines.

The Roentgen or X-Rays

It was discovered by Professor Conrad Roentgen in 1895, that if a current of electricity be passed through a certain form of glass bulb, from which most of the air has been exhausted, a disturbance is produced in the ether that bears some resemblance to light waves. For want of a better name to give to a disturbance which was not well understood, Roentgen called his discovery the X-ray, but it is now frequently called in his honor the Roentgen ray. The nature of this disturbance is not yet known, but as it does not affect the eye it is not light. In Fig. 14 T is the glass vacuum tube and B the battery from which a current of electricity is sent through the tube. The wires of the battery are connected with the electrodes *a* and *b*, the former of which consists of a concave disk of aluminium, and the latter of a flat disk of platinum. The X-rays are discharged in straight lines as shown in the figure. The most striking property of the X-ray is its power to penetrate many substances that are impermeable to light. All vegetable substances, and the flesh of animals, are penetrated by it very readily. Glass, metals, bones, and mineral substances generally, are opaque to it. Consequently when a limb, or even the body of an animal, is exposed to X-rays they pass through the fleshy parts, but are stopped by the bones. Certain substances have the property of glowing, or becoming *fluorescent*, when exposed to the X-ray, and when screens of paper are coated with these substances they form a convenient means of detecting the presence of X-rays. By holding the hand between a tube that is giving off X-rays and a screen of this kind, the bones of the hand will be outlined in shadow on the screen, and the rest of the surface will glow with a greenish

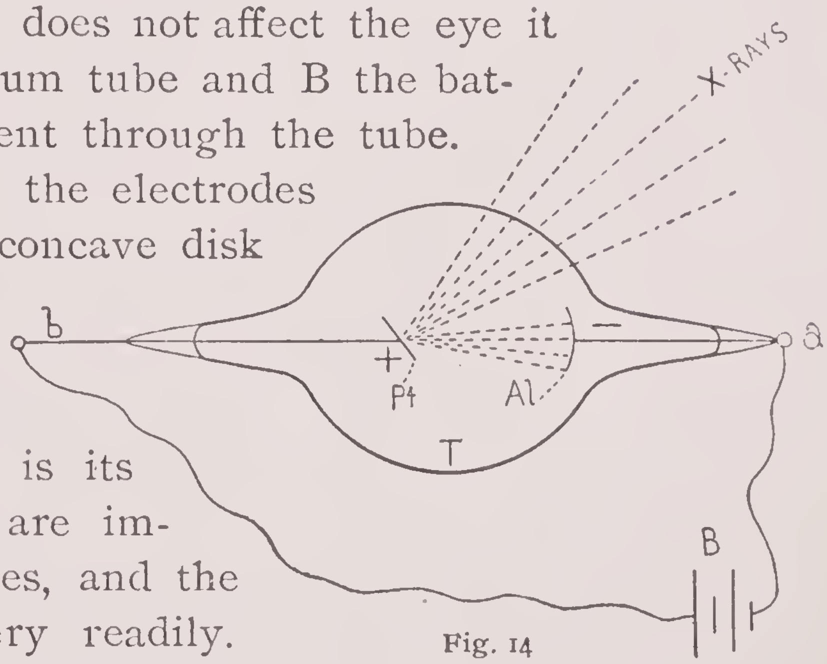


Fig. 14

light. If a bullet or other piece of metal has become imbedded in the body, it may easily be located, if it is not in a bone, and the extent of an injury to a bone or a joint may be plainly shown. For this reason the X-ray is now widely used by surgeons.

WIRELESS TELEGRAPHY

While Professor Morse was experimenting with his system of telegraphy in 1842, he sent signals across the Susquehanna River at Havre de Grace, Maryland, without metallic connections of any kind. His wires were stretched along the banks of the river.

James Lindsay, of Dundee, in 1859, read a paper before the British association for the Advancement of Science, in which he stated that if wires were run along the shores of Great Britain and America, and these charged by batteries, it would be possible to send messages across the Atlantic. At the Royal Society in 1864 Clerk Wallace read a paper defining ether waves. He mentioned electro-magnetic waves and was led to conclude that the velocity of these waves is equal to that of light. This assumption has since been proved to be correct.

In 1879, Professor D. Hughes, while experimenting with the microphone, discovered that when that instrument was several feet from a telephone, and not connected with it in any way, he was able to produce sounds from it.

In 1885, Sir William Preece, of the General Post Office of London, England, arranged wires in the form of two disconnected squares measuring 440 yards on a side. These squares were one quarter of a mile apart. He was able to send currents between these two squares over the intervening space. In 1886, he arranged two parallel wires four and one-half miles apart and sent signals across this distance.

In 1889, Sir Oliver Lodge obtained the first definitely successful results from signalling by means of an apparatus in which the coherer was used. In 1890, Professor Branly's coherer, in which metal filings were used, was first publicly described.

In 1892, Sir William Preece set up communication between the island of Flatholm, in Bristol Channel, and Lavernock, three and one-third miles distant on the Welsh coast.

In 1894, Dr. Rathenau and Professor Reubens sent a signal across the Wannsea, at Potsdam, a distance of three miles. They used a base line of wire 550 feet long and utilized the earth currents.

In 1897, Marconi, by using the ærial, or high wire, sent signals from Flatholm to Lavernock.

In 1898, Sir William Preece, passed favorably upon Marconi's system, and it was established between the royal yacht "Osborne" and Osborne House, Isle of Wight.

In 1899, Professor Braun took out patents abroad on the wireless system. In the same year Professor Shunder Bhose read a paper before the Royal Society in which the action of the coherer was fully discussed.

In 1901, Marconi had set up his apparatus at Hospital Point, in Newfoundland, and in Poldhu in Cornwall. In December of that year he received the signal "S" transmitted across the Atlantic.

In February, 1902, the S. S. "Philadelphia," remained constantly in communication with the Marconi station at Poldhu for a distance of 1,500 miles.

Thus far the communications had been merely signals. In December, 1902, Marconi sent the first trans-Atlantic message of words from the station at Glace Bay, in Cape Breton, Canada, to Poldhu in Cornwall, England. It was a message from Lord Minto the Governor-general of Canada, to Edward VII., King of England. So gratifying was the success of the experiments that preparations were immediately made for the establishment of the system upon a commercial basis. The system comprises a tall ærial wire, which is proportionate to the distance of communication, to catch the impulse of a single spark. The impulse is transmitted down the wire to a coherer. In the coherer are several silver plugs, a fraction of an inch apart, between which are minute particles of nickel and silver, so fine that they have been sifted through silk. These have the power of being alternately good and bad conductors of the Hertzian waves. They are good conductors when the passing current welds them into a compact mass, and poor conductors when they fall apart by the force of a light blow. The Morse alphabet is used and when the Morse instrument prints a dot, a tapper strikes a blow upon a glass tube and this causes the fine metal particles to fall apart and to cease to conduct the current at the home battery. The impulses through the ether are not strong enough to print a dot or dash, but they open and close a valve which lets in or shuts out the current of the home battery. Important improvements have been made by Marconi, by which he is able to reduce the height of the ærial wires and to use a weaker current. Peter Cooper Hewitt, in 1903, invented the mercury vapor interrupter, which is designed to increase the force and effectiveness of a current, and to enlarge the field of operation. The publicity of the message or the possibility of its collection by rivals is overcome by the use of secret codes. Professor William Marconi was born in Bologna in Italy in 1875. His father was Italian, but his

mother was British. He took up the study of electricity and made many independent experiments before he was aware of the important discoveries made by Professor Hertz, who, in 1887, ascertained that sparks from a Leyden jar can be transmitted across open areas in every direction and collected by wires. Marconi went to England and interested Sir William Preece of the General Post Office, and the department assisted him in carrying out the development of his plans. In 1899, he came to America and attracted attention by reporting the results and progress of the international yacht races by his system.

Compass, Mariner's.—An instrument for indicating the magnetic meridian, by which sailors at sea are enabled to steer their course when out of sight of land and when neither sun nor stars are visible. The magnetic needle is subject to slight variation with latitude, so that it usually points E. or W. of the true north, and it is affected also, and often disastrously to ship and mariners, by the reaction of the ship's iron, in the case of steamers, upon the magnet. With precautions so as to overcome these variations, the value of the magnet is great, since once knowing where the north lies the steersman can, by a glance at the circle-card attached to the bar magnet in the compass box, and marked with the 32 equal angles or "points" of the compass, find his true path across the waters. The free suspension and movement of the needle are usually secured by attaching to it a cap of agate or ruby, which rests on a hard sharp point. The directive power of the magnet seems to have been unknown in Europe till late in the 12th century, though it is affirmed that the Chinese were aware of it at a very remote period, using the lodestone first and later the magnetic needle. The surveyor's compass is an instrument used in surveying for measuring horizontal angles.

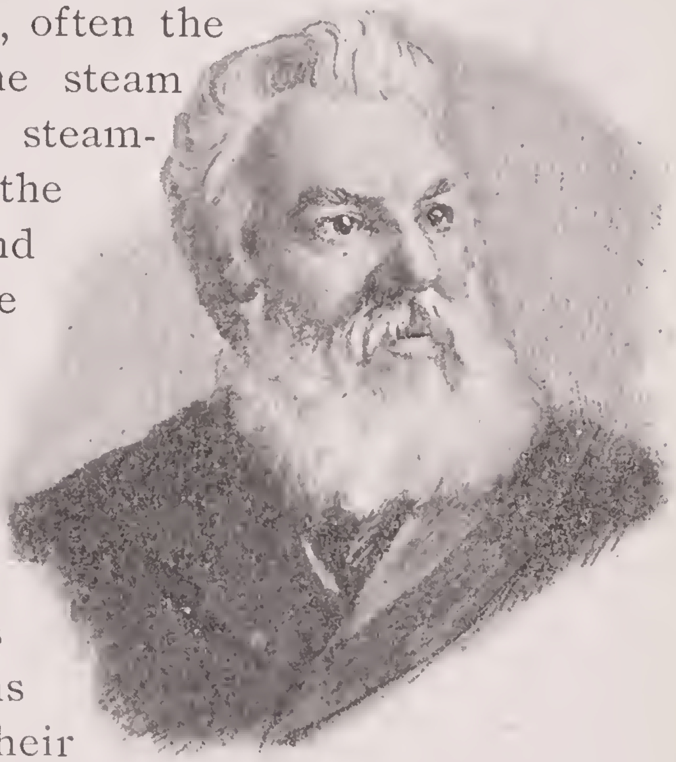
Boxing the Compass is a rehearsal of the points, half-points and quarter-points of the compass. Commencing with the North and going around with the sun this order is observed:

North.
North by East.
North North-East.
North-East by North.
North-East.
North-East by East.
East North-East.
East by North.
East.
East by South.
East South-East.
South-East by East.
South-East.
South-East by South.
South South-East.
South by East.
South.
South by West.
South South-West.
South-West by South.
South-West.
South-West by West.
West South-West.
West by South.
West.
West by North.
West North-West.
North-West by West.
North-West.
North-West by North.
North North-West.
North by West.
North.

ALEXANDER GRAHAM BELL

The whole world talks through his telephone.

It is probably true that not one of the great inventions that human genius has given to the world was conceived and brought to perfection by a single person. Each of them was made applicable to the uses of man by a system of evolution. The idea that came to the first mind in the series was but the germ from which grew the perfect scheme, by gradual development, often the work of many years. Such was the origin of the steam engine, and its application to the railway and the steamboat, the machinery for spinning and weaving, the sewing machine, the grass and grain harvester, and the telegraph. So it was with the telephone, the name most prominently identified with which is that of Alexander Graham Bell.



When, about the year 1878, the first practical telephone, by which the articulate sounds of the human voice were distinctly transmitted long distances, with the aid of the electric current, was produced, the world was incredulous. Few persons were able to believe, except on the testimony of their own ears, that the words and tones of the voice could be carried hundreds of miles, and delivered to the receiver in such manner as to be easily distinguishable. Even then, most people said that the telephone was but an ingenious plaything, that would amuse for a time and perhaps interest the curious. Few believed that it would prove to be of practical benefit. But the telephone made its way rapidly. When a few working lines had been established, the popular mind was quick to grasp its convenience and utility. It spread like a contagion. Telephone systems were established in cities and towns, and long-distance lines were built, by which instantaneous verbal communication between points far remote from each other was made possible. The telephone is no respecter of language, and it was but a few years till the "Hello!" was heard around the globe. The telegraph revolutionized the means of communication, and the telephone was another great leap forward. It has to some extent supplanted the telegraph for long distances, but for local use, affording quick communication in a city or other community, for

business or social purposes, it has come to be regarded as a thing indispensable. One wonders how he ever got along without it.

It will be interesting to note the beginning and the development of this wonderful accessory of our modern civilization. In 1854, Bourseul, a young mathematician and physicist, communicated to a Parisian newspaper a project for transmitting speech by electricity. He proposed that the vibrations which produced the sounds of the human voice should be delivered upon a delicately flexible disk, which should make and break connection with a battery by its own vibrations and so reproduce the same vibrations, and consequently the same sounds, upon a like disk at the other end of the connection. It will be seen that, in a broad way, this published project was a close anticipation of the telephone.

In 1861, Reis, a German school-teacher, exhibited at Frankfort an apparatus called a telephone, in which the vibrations were transmitted and reproduced in the manner indicated by Bourseul. The device was successful in reproducing musical sounds and vocal inflections, but not practically so in reproducing the articulations of speech. Successive improvements made it an interesting piece of philosophical apparatus, and a possible telegraphing instrument for such as chose to use vocal signals, but it never became a speaking telephone.

In 1869, Dr. P. H. Van der Weyde, of New York, produced a singing telephone, on the principle of the Reis instrument, but it would not reproduce articulate speech. In the same year, Daniel Drawbaugh, of Milltown, Pennsylvania, an ingenious but unprosperous mechanic, with some practical electrical knowledge, repeatedly exhibited a rudely constructed but perfectly operative speaking telephone, and even made some small and occasional use of it in his own little business affairs. But he seems not to have appreciated its commercial utility or value, and he made little effort to improve or introduce it, though he often talked in a large strain of its possibilities. Crude as this apparatus was, it varied the power of the current to conform to the sound vibrations, and for that reason was able to reproduce speech.

On January 20, 1876, Alexander Graham Bell, a college professor, of Salem, Massachusetts, executed the specification and claim for an improvement in telegraphy. A few days afterward, he delivered to the Hon. George Brown, of Canada, a similar document, to be used in preparing an application at London for a British patent. On February 14, 1876, Bell's application for the American patent was filed in the patent office at Washington. Later in the same day, a caveat was filed there by Professor Elisha Gray, of Chicago, for a new art

of transmitting vocal sounds telegraphically. A patent was granted to Bell, but it was attacked by Gray and others, and a long litigation followed. The matter was in the courts for several years and the contest was conducted on both sides with extraordinary energy. The most eminent legal counsel in the country were engaged, and when they met in argument it was a battle of giants. Eleven years after the patent had been granted to Bell, the question came before the United States Supreme Court for final decision. The court sustained the Bell patent, three of the justices dissenting. Chief-justice Morrison R. Waite, a most upright, conscientious, and laborious man, unwilling to burden any of his already overladen associates with the drawing up of the majority opinion, in one of the most voluminous and intricate cases that had ever come before the court, took that duty upon himself, though he really had the least time of any to devote to it. When the day came, he was too weak to read the opinion, which another member of the court read for him, and after listening to the dissenting opinion delivered by Justice Bradley, he went home and took to his bed, from which he never rose again.

As the perfecter and introducer of the telephone, Bell rose to great fortune and a high fame, not only at home but abroad. Europe has accepted him unreservedly as belonging to the category of great inventors, though she no more regards him exclusively as the developer of the telephone than she does Morse of the telegraph, or Fulton of the steamboat. The great day of the telephone lies ahead, and the continual advances in electrical science indicate that the talking machine is yet but in its rudimentary stages. When telegraphy becomes wireless, telephony must follow the fashion, and so with other principles dealing with the motive power of the telephone.

It has been the contention of Gray that he was the author of the "variable resistance" method, which gave to the telephone its practical value. But it is not in the least a question whether Bell could have devised the method for himself. That he could and would have devised it, had Gray never been born, is as certain as anything human. He was an electrical expert and a capable electrical inventor; he was after a speaking telegraph and knew the conditions of the problem, and there is irrefragable proof that from June, 1875, which is admittedly earlier than Gray's conception of the variable resistance to produce the variable current, Bell was headed straight toward the right solution. As between Gray and himself, the question in its farthest limit is only whether or not Gray was a little ahead of him. Historically considered, the question is not important, since the unlettered mechanic, Drawbaugh, was years ahead of both. The case is analagous to that of the famous barbed-wire monopoly, established on

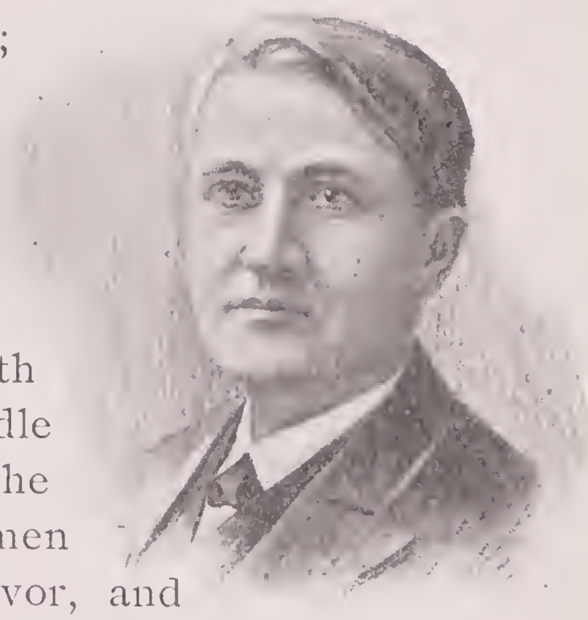
two patents afterward found to be invalid by reason of a prior French invention, and that in turn long antedated by the publicly exhibited but unfollowed invention of a thriftless, vagrant and intemperate mechanical genius in Pennsylvania. So far as Bell is concerned, it is sufficient to know that his claim was sustained by the highest judicial tribunal in the land, after a patient, full and exhaustive hearing.

Professor Bell is a Scotchman, born at Edinburgh in 1847, and a graduate of its high school and its famous university. At the age of twenty, he went to London and continued his post-graduate studies there, but his health failed and in 1870 he went to Canada with his father. In 1872 he removed to the United States and engaged in teaching his father's distinguished system of deaf-mute instruction, popularly called visible speech, and intended to impart the vocal sounds to deaf mutes and so enable them to converse with their fellow-men. He became a professor at Boston University, and there continued the studies and experiments that had long interested him as to the transmission of sound by electricity; and in the draft specification for a British patent that he prepared in January, 1876, and which admittedly contains nothing but his own original ideas, the progress that he had made clearly appears. That specification is for a vibratory, or undulatory, current in telegraphy, in place of the intermittent current; the vibrations of the current are to correspond with the vibrations of the inducing body — that is, to the pitch of the sound produced; the current is also to respond to the air movements caused by the sound vibrations, and the telephone is strongly suggested when he says: "When electrical undulations of different rates are simultaneously induced in the same circuit, an effect is produced exactly analagous to that occasioned in the air by the vibration of the inducing bodies." After this, it is quite natural to find him enumerating "the telegraphic transmission of noises or sounds of any kind" as among the uses of the vibratory magnet apparatus that he then proposed to adopt for his vibratory current, and the armature of which, he said, could be set in motion by means of the human voice. This was not the "variable resistance" method which produced the practicable telephone and made Bell's great fortune, but it shows that he was in the midst of the field and was feeling his way forward with the assured skill of a master. It tends also to show that if Drawbaugh's abandoned invention had gone to the general use, Bell would have found a large measure of reputation and reward as an improver of the telephone, from the practicable but still rudimentary stage at which Drawbaugh left it.

THOMAS ALVA EDISON

Something about the « Wizard of Menlo Park.»

Ohio, succeeding to the title long held by Virginia of « Mother of Presidents," is justly proud of the circumstances that five chief magistrates — Grant, Hayes, Garfield, Harrison and McKinley — were native Buckeyes, though Grant and Harrison came to the presidency from other states. Sherman, who shared with Grant the honors arising from the Civil War, was an Ohioan; and Sheridan the last of the trinity of great Union generals, though born in New York, went to West Point from Ohio, the home of his adoption. Ohio was early favored in the character of the people attracted to her borders. The descendants of the New England Puritans here met and intermarried with the descendants of the sturdy Dutch of the Middle states, and of the Cavaliers and Scotch Irish of the South. Such a commingling of blood produced men well fitted to lead in every field of human endeavor, and may reasonably account for Ohio's prominence during the dark days of civil war, and her prominence in the domain of national politics almost continually since the war. But Ohio has the further distinction of being the birthplace of a man whose scientific achievements have carried his name wherever civilization exists, and whose works will endure long after her statesmen and military captains have passed into forgotten history. That man is Thomas Alva Edison, the most prolific of American inventors — which means of all inventors, for in this field America magnificently leads England, France and Germany. At this time (1901), Edison is but fifty-four years old, yet between 1870 and 1900 he had taken out seven hundred and twenty-seven patents. Edison is descended from a long-lived race and this, with his simple tastes and quiet habits of living, should insure him a long lease of life. He should be comparatively young at eighty, and possibly his best work is yet to come.



Edison was seven years old when his parents left the quiet Ohio village of Milan, where he was born, removed to Michigan and settled in the bustling town of Grand Rapids. His mother had been a

school-teacher before marriage, and was a woman of marked individuality, with more than the average culture of that day. From her, Thomas received both his mental poise and intellectual training, for his school attendance was limited to a short term of two months. By his mother he was instructed in the fundamental branches of knowledge and, what is still better, in the objects of knowledge. Her personal experience taught her what many public educators have since learned, that to assist the intellectual development of youth by training them to think logically, is more important than to require the performance of a certain amount of routine work. Mrs. Edison early implanted the love of learning in young Edison's mind, and at the age of ten he had read the "Penny Encyclopedia," Hume's "History of England," "History of the Reformation," Gibbon's "Rome," Sears's "History of the World," several volumes of chemistry and other scientific works. He read them faithfully, too, never skipping a word, and fixing his mind upon every page.

It is the habit of American lads to strike out early for themselves — to see the world, to take their place in it and to relieve their fathers of their support. In this, as in other respects, Edison was typically American. He was twelve years old when he seized the opportunity to sell newspapers on the Grand Trunk Railway. He handled the miscellaneous class of merchandise that is sold by the train-boys to-day, and, for a youngster, built up a flourishing business. He continued this work four years, accumulating in all nearly two thousand dollars, which he dutifully gave to his parents. The accidental circumstance of rescuing from a passing train the infant son of the station agent at Mt. Clemens, interested the father in young Edison and, as a reward, he taught him telegraphy.

Edison's novitiate lasted five months and then his wandering career began. After a few months' employment at Port Huron, where he acquired further experience, Edison drifted into Canada, finding employment with the Grand Trunk Railway, as night operator at Stratford. Here his genius for invention was first displayed. To guard against sleeping on duty, the operators were required to report every half hour to the wire chief, usually the night train dispatcher. At the expiration of thirty minutes, beginning at nine o'clock, each operator was to open the circuit and write the word "six," following it with the figure "6" and sign his office call. The operator who did not write his "six" was supposedly asleep, and, as soon as aroused, was sternly lectured for his delinquency. Edison found a way at once of maintaining his record and spending the night in refreshing slumber. He rigged a wheel with Morse characters on the rim in such a way that when turned by a crank it would "six" beautifully. The

watchman turned the wheel while Edison slept. Edison's failure a little later to deliver a train order nearly resulted in a collision, and he hurriedly left Canada and returned home to avoid the consequences.

With increased experience and skill, Edison gradually drew away from railroading and found employment with the Western Union Telegraph Company. From Indianapolis, his first assignment as commercial operator, he went to Cincinnati and thence to Memphis. Intoxicated with the pleasure of travel, which the demand for operators made easy, he planned a trip to South America. He had gone as far as New Orleans, when he decided against the wisdom of his course, returned North and accepted for a second time a place in the Cincinnati office. He was now twenty years old and rather tall for his age, having apparently attained his full stature. He was thin and hollow-chested, and his clothing hung loosely about him. He was healthy enough and capable of prolonged physical exertion, but he looked unwholesome and ill nourished. Then, as now, Edison lived much within himself, and his face, when sending and receiving dispatches, wore the far-away look of the student and dreamer. He was not unpopular with his fellows, but by the most of them he was regarded as "queer," owing to his preoccupied air and his experiments in electrical science. The unmarried telegraphers of that day were true "Bohemians," who lived only in the present, with little thought for the morrow. Their leisure hours were spent after the manner of many young men who live in large cities, and they could not understand how Edison, himself a young man, could hold different views of life.

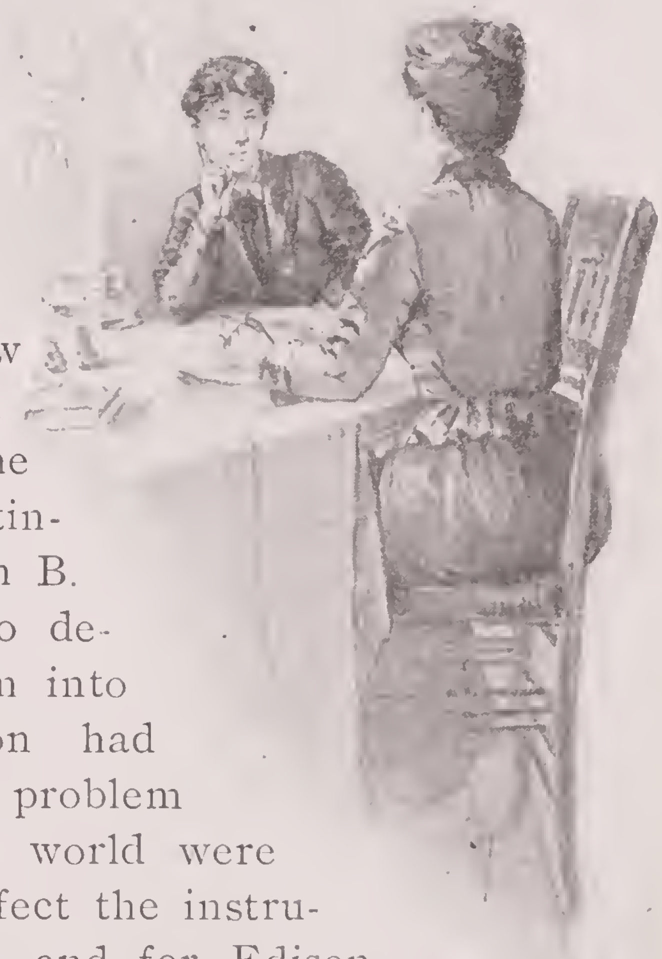
It is evident that Edison could have had little in sympathy with the other operators, except the common vocation and that fraternal feeling which has always strongly existed among telegraphers. Yet his social side of life was fairly developed. He had at least the American appreciation of the ridiculous, and heartily enjoyed a good story. He was witty and given at times to punning; but these glimpses of his character were seen only at intervals. They appeared late at night, when the work was well up and the operators were waiting for "good-night" and the usual late supper before retiring. Edison cared nothing for late suppers or convivial pleasures of any kind. He had no vices, if his fondness for tobacco, which he chewed continually, be excepted. For him, drink, billiard playing, or society outside of the office, had no attractions. He was not a woman hater, for he has since been twice happily married, but diffidence made association with women, at that formative period, painful to him. It was bad enough if they were old and ugly, but if

young and pretty, as many of the visitors to the operating room were, Edison would seek instant refuge in the battery room or other convenient place. Perhaps his fear of the sex was not entirely due to diffidence. His careless appearance may have had its influence, for that appearance was far from prepossessing. He was awkward and ungainly and always ill dressed. His clothes were worn until the rebellious trousers frayed at the ankles and insistently bagged at the knees. The coat kept its place by a single button, and the torn lining would display itself on the outside. His carelessness in dress made Edison the subject of sharp criticism from the more fastidious of his associates, and some of them socially boycotted him. On one occasion, several of the "dressy" young men complained to the night manager that Edison ought to be instructed to change his wardrobe or his job. The night manager, an amiable old gentleman, not too fastidious himself in the matter of dress, promised to speak to Edison, but it is not recorded that he did.

As a matter of fact, the chiefs of departments concerned themselves little with the morals of their young men, and less with their personal appearance. The work in the office was heavy and expert operators were scarce. Edison was a clever operator and his habits were good, and this was enough to win him high esteem from his official superiors. It is too often the fashion, when men have become famous in some field of human activity, to endow them with unusual qualities during that period of their lives when they were laying the foundation of future greatness. Their boyish escapades are distorted into deeds of heroism, the smart sayings of childhood are exaggerated into great profundity of thought, and every little incident is given a dignity and importance beyond its original worth. But it is only simple truth to say that in this vocation, Edison had no superior. He brought to his work three necessary qualifications —excellent memory, rapid penmanship and sharp ears. Without these one cannot succeed in telegraphy. Rapid penmanship is not so necessary, now that the typewriter has taken the place of the pen in receiving, as it was in Edison's day, when the typewriter did not exist. This also was before the invention of the duplex and the quadruplex instruments, which have doubled and quadrupled a wire's capacity. There were fewer wires at that time, for this period of Edison's life was shortly after the Civil War. If the limited facilities of the Western Union Company at that time be considered, the amount of business it handled was relatively as large as that of today, while the working force was relatively smaller. These condi-

tions necessitated great speed on important wires, and to such wires only the best talent could be assigned.

During his six months' service in Cincinnati, Edison received the Associated Press dispatches. He came on duty at half-past six in the evening and remained until "good-night" was flashed from New York. If the weather was pleasant and the wires worked well, he finished usually at one o'clock. On rainy nights, when there was more or less escape of electricity, and the dots and dashes came faintly and indistinctly over the wires, "good-night" was delayed until the early morning. Once, a very bad night in December, Edison was relieved by the day operator, not having left his chair for fourteen hours. After an exhausting night's work — and there is no work more exhausting than telegraphy — he would sleep for a few hours and awake with his energies quite restored.



Edison left Cincinnati with an unusually fine record, and accepted an appointment in the Western Union Telegraph Office at Boston. In the New England metropolis he found, for the first time in his wandering life, congenial associations. The manager, George F. Milliken, was himself a distinguished electrician; and there, too, he met Joseph B. Stearns, an inventor of note, and both helped to develop the budding qualities that later brought him into prominence. Before he left Cincinnati, Edison had given much thought to duplex telegraphy, a problem upon which the best minds of the telegraphic world were then engaged. It was reserved for Stearns to perfect the instrument that doubled the carrying capacity of a wire, and for Edison, a few years later, to make another forward step by inventing the quadruplex, which revolutionized the practice of telegraphic art.

Yet Edison was to suffer many vicissitudes before the quadruplex, his first notable invention, should take definite form in his brain. Of the practicability of the duplex he had no doubt, and he foresaw that the quadruplex would logically grow out of it, as it did a few years later. Meanwhile he invented a vote-recording machine for legislative bodies, and a private-line printer, but, handicapped by poverty, he followed the usual course of inventors and sold the printer for a song. The tide in Edison's affairs that bore him on to fame and fortune awaited him in New York, where, in 1870, he arrived penniless. Unsuccessful in finding employment with the commercial telegraph companies, he no doubt "suffered not only for food

but for clothes, while he tramped the streets for a job," as biographers have told us.

Chance took him one day into the office of Law's Gold Reporting Telegraph Company. The instrument that reported the gold quotations was out of order and the inventor was in despair. Edison quickly discovered the source of trouble and the company immediately employed him. This was the turning point in his career. His new employers, clever, up-to-date business men, recognized his talent and encouraged him to develop it. This he was not long in doing, and the original printer was soon discarded for one of Edison's own invention. After a time he associated himself with the Gold and Stock Telegraph Company, of which General Marshall Lefferts was president. Here, again, under the stimulus of encouragement given him by General Lefferts, he invented several stock printers which the company decided to buy. This brought Edison into his first transaction of business, his knowledge of which was in the opposite ratio to his inventive genius. He hoped to receive an offer of five thousand dollars; yet it was but a hope, and half of that amount would have satisfied him. To his astonishment, the company offered him forty thousand dollars, and when a check for that amount was handed him, he was so ignorant of banking methods, that he could not cash it without assistance.

With this money he opened a small workshop, where a number of printing telegraph machines were invented. Expanding business brought large pecuniary rewards, which were immediately invested in fresh experiments. In this respect Edison differed from ordinary inventors. He was not satisfied merely to earn money. For money, as money, he cared little, his personal wants being few and easily satisfied. But money was needed to widen the circle of his experiments, and he sought it for that reason. All this time he was living as plainly as in his younger days. He labored early and late, finding his pleasures in his laboratory and in consultation with his expert assistants. He developed remarkable powers of endurance, and it is recorded that on one occasion he worked for sixty hours without sleep and almost without food, to perfect an instrument for which a purchaser was waiting. Then he slept for thirty-six hours and awoke for another long turn at the wheel. It has been well said that this ability to dispense with sleep and sustenance, this swift power of recuperation, which can be found only in a physique the pure currents of which have never been vitiated by dissipation, are a potent argument for total abstinence. Edison's

severe and protracted labors owe their sustained brilliancy to no artificial stimulant, and nature finds it easy to repair the ravages inflicted by painful or continuous endeavor.

During the first years of Edison's work as inventor, he gave his efforts to improvements in telegraphy, and 1874 witnessed the birth of the quadruplex. This invention he sold to the Western Union Telegraph Company for a moderate sum, that was soon exhausted on the development of the octoplex, an instrument to transmit eight messages simultaneously over one wire. The use of the quadruplex, by lessening the expense of construction and repair, has added to the profit of the Western Union Telegraph Company probably a million dollars a year.

Edison's work of later years has been still along strictly electrical lines, the most notable exception being the phonograph, which he developed from a mechanical toy into a useful business agency hardly less important than the typewriter. It is, however, the electric light and the telephone that have given Edison preëminence and made him many times a millionaire. He was not the original inventor of either, but he gave to both, especially the electric light, a commercial value. Until his improvements were made, electric lighting had not advanced far beyond the embryonic stage. It has been fairly said that at no time has Edison advanced a claim of original discovery in connection with the electric light; but he does claim, with undeniable justice, that by him the immature and scattered principles of his predecessors were perfected, and welded into one symmetrical whole. Upon this point a biographer says: —

"In his hands the incandescent electric light was withdrawn from the fruitless seclusion of the laboratory and transferred to the plane of practical utility. From the costly toy, interwoven with intricate mechanical difficulties, and gifted with but a limited period of existence, it has become an all-important factor of public life, embodying the features of evenness, power and inexpensiveness, which were so conspicuously lacking in former systems. Not that we would deny the indispensable basis afforded by prior investigations, or the undeniable talent and energy displayed by former scientists; on the contrary, we are disposed to admit, in a large measure, the self-evident proposition advanced in our question. At the same time it may be maintained, that the very excellence of these methods enhanced the difficulties of Edison's task, and threw into broader relief its superior merits."

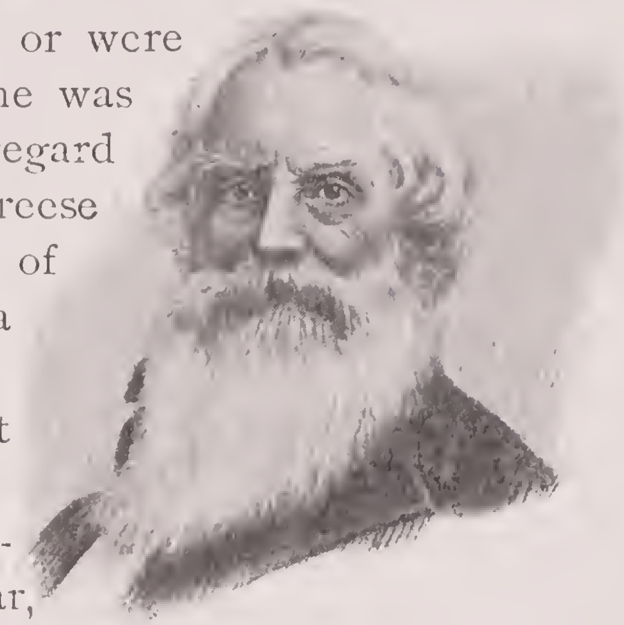
Such, in brief, is a typical American career. It is that of a man starting from boyhood with only the advantages given him by nature, and by sheer force of will, self-denial and untiring energy, developing his natural talent and becoming one of the master minds of the day. To his abstemious habits and simple mode of living, Edison's success is largely due. Many men as brilliant as he have yielded to the fascinations of social life, and so wrecked a career that if properly directed, might have rivaled that of the once obscure telegrapher. Edison's life is an instructive object lesson to American youth, in showing what natural talent, backed by good moral standards and sustained by industry, may accomplish. His works are his monuments, and being inseparable from him, his fame will be as enduring as themselves.

A lesson to be learned from the life of Edison is the success that comes to one who pursues a single, well-defined purpose — one in whom is "no variableness, neither shadow of turning." There is many a man whose brain is over-fertile, in which new ideas, in rapid succession, spring up and grow like plants in a hothouse. He follows one of these ideas and applies his energies, for a time, to its development; then his mind is diverted to a new one and the other is laid aside, perhaps never again to be taken up. His genius may be brilliant, but its power is dissipated and destroyed by its fickleness. His conceptions may be original and valuable, but he lacks that power of concentration, of sustained effort, by which, alone, an idea is wrought out to a conclusion. There have been many such, whose prolific minds brought forth inventions, each of which contained the elements of success and fortune, but who have utterly failed, because of dissipation of effort. Happy the man whose clearness of perception enables him to decide upon the line of thought and labor for which he is best fitted, and who has the power to resist all diverting influences. He who has fixedness of purpose and steadfast perseverance rarely fails of the coveted reward.

SAMUEL FINLEY BREESE MORSE

Who started the click of the telegraph.

No longer ago than the early seventies, a familiar figure in the city of New York was that of a venerable gentleman who was almost daily seen about the telegraph building, corner of Broadway and Dey streets. He was tall and of slender build, but erect and graceful in carriage, despite his eighty years. His features were attractive, even to strangers; to those who knew him, or were told his name and what he had done for mankind, he was an object of more than ordinary interest, and of regard akin to reverence. That man was Samuel Finley Breese Morse, one of the world's great benefactors, inventor of the magnetic telegraph. He was the first to find a practical application for the electric current—that mysterious yet mighty force of nature—and make it the useful servant of man.



Within the last two decades of the nineteenth century, and within the memory of those who in this year, 1901, are just passing the line that marks the entrance into manhood and womanhood, the development of electrical science, and of the use of electricity for light, power and other purposes, has been nothing less than amazing. Morse fixed the attention of the world to the fact that electricity could be made subservient to the human will. This set other men to thinking, and the wonderful results of later years were the natural sequence. The direct achievement of Morse revolutionized the means of communication. It brought the ends of the earth together by the annihilation of space and time. At the same instant that a message is put upon the wire, its words are being written as the letters are clicked to the practiced ear of the operator, ten thousand miles away.

A troubled life was that of Morse, but he lived a third of a century after success had been gained, to receive large pecuniary reward, and to find himself one of the great men, not alone of his day, but of all time. The system of telegraphy which he perfected is used exclusively in this country and it will probably continue to be the leading system of the world. Of more than one hundred devices that have been made to supersede it, not one has done so, and it is

employed on ninety-five per cent of all the lines in America and in Europe.

Electricity, as a force, was known before Morse was born, but he it was who utilized the crude conceptions of the earlier scientists and made it the medium to convey and register thought. Morse was forty-one years old before the plan of the recording telegraph filled his mind. He was fifty-two when Congress authorized the construction of the first telegraph line, between Washington and Baltimore. The intervening period was one of great discouragement. He was so pinched by poverty that at times he was upon the verge of starvation. But neither discouragement nor the keen sufferings of penury could subdue his courage, and with success came such honors as are given to few men.

The subject of this sketch was born in Charlestown, Massachusetts, April 27, 1791, the son of Jedediah Morse, a clergyman. His school advantages during boyhood were limited, but he was bright and apt to learn and in mental attainments was in advance of most lads of his years. At the age of fifteen he was fitted to enter Yale College, from which he was graduated at nineteen, in 1810. He improved well the opportunities which he enjoyed at Yale. Among these it was his privilege to attend the lectures of Professor Silliman and other celebrated scientists on chemistry, galvanism, electricity and kindred subjects. He profited much by these lectures. They sowed in his mind the seed which, more than twenty years later, sprang up and brought forth fruit "an hundredfold."

It was not science, however, that claimed his attention and directed his effort upon his graduation. He possessed a remarkable talent for painting, and spent several years in London studying that art under the best masters. He became one of the foremost of American artists. He was commissioned by the corporation of New York to paint a portrait of Lafayette, then in this country, and was later one of the founders and the first president of the National Academy of Design. During the years from 1826 to 1829 he lived in New York, pursuing his vocation, but his success was not commensurate with his ambition. Poverty, so often the lot of genius, pressed him sorely and continually, preparing him, unconsciously, for the more severe trials through which he was yet to pass. After a time, the tide of ill fortune turned. His sittings increased and the most eminent New Yorkers gave him commissions. Success but stimulated him to greater effort. He resolved to perfect his art in Italy, and thither he journeyed at twenty-eight, remaining abroad three years.

Before his return to America, Morse spent a brief time in Paris. While there, he was thrown into the company of scientific men, from whom he learned of recent experiments by Ampère with the electro-magnet. The interest in this subject, which long had been smoldering in the mind of Morse, was kindled into a flame. The opinion was expressed to him, based upon the experiments of Benjamin Franklin and Ampère, that electricity would pass instantaneously over any length of wire. Morse then said, "If it will go ten miles without stopping, I can make it go around the globe." Immediately it occurred to Morse that if the presence of electricity could be made visible in any desired part of the circuit, it would not be difficult to construct a system of signs by which intelligence could be instantly transmitted. The thought thus conceived took strong hold of his mind in the leisure that the homeward voyage afforded, and before landing he had planned such a system, with mechanical devices to carry it into effect.

From this hour began a struggle that lasted twelve years, "a struggle," in the words of his biographer, "more severe, heroic and triumphant than any other which the annals of invention furnish, for the warning and encouragement of genius." Absorbed in the one idea of a recording telegraph, yet wholly depending upon the brush for the necessaries of life, it became impossible to pursue his art with that enthusiasm and industry essential to success. Nor could he perfect his invention while he continued painting.

His situation was desperate. The father of three young children, now motherless, his pecuniary means exhausted by his residence in Europe, he was at his wit's end. He had visions of a telegraph that should bring the ends of the earth into instant intercourse. Thoughts of fame came to him by day and by night, kindling his ambition and nerving him to greater exertion. He was poor, and believed that wealth, as well as usefulness and fame, was within his reach. It was the old story repeated, and to be repeated, of genius contending with poverty. He knew what rapid progress the world was making in science and art; the idea that he had started might spread like electricity itself, far and wide; the danger was great that some one else, with more time and means, would seize the thought, reduce it to practice and present it to the world, while he was brooding over it in melancholy indecision and helplessness. His letters to friends in former years had frequently indicated a tendency to despondency. He was now sinking very low. The apprehension that he might not complete his work filled him, at times, with anguish.

After patient, persistent and long-continued effort, through much privation and suffering, Morse perfected his invention and took it to Washington. A bill appropriating thirty thousand dollars for an

experimental line between Washington and Baltimore, to test its practicability, was introduced in the House of Representatives. Four weary years elapsed before it was passed. To a man of his delicate sensibilities, the coldness and neglect of Congress were well nigh unbearable. Day by day he stood at his instrument, meekly and sometimes tearfully exhibiting it. Many scoffed covertly, if not openly, declaring the scheme to be but the vagary of a madman. His coarsest critics were among public men whose anti-progressive spirit and lack of discernment long delayed the passage of the momentous measure.

There were others, however, who gave him cordial and energetic support. Their names should be written in letters of gold, that all men may know them. First was the commissioner of patents, Ellsworth, of Connecticut, whose state is credited with more patents than any other. Of members of the House, there were Seymour, of Connecticut; Kennedy, of Maryland; Mason, of Ohio; Wallsee, of Indiana; Ferris and Boardman, of New York; Holmes, of South Carolina; and Aycrigg of New Jersey.

A favorable report from the commerce committee, to which the bill had been referred, brought it before the House in the last fortnight of the session, eleven years after the plan of telegraphy had dawned upon its inventor's mind. The debate that followed is not preserved in the journals of the day or in the official reports. It is well, perhaps, that it is not, for nothing less creditable to the intelligence of the American Congress has been recorded. One facetious gentleman, Mr. Johnson, of Tennessee, said that the science of Mesmerism should not be overlooked, and proposed that one-half of the appropriation be applied to its development. Mr. Houston, of Texas, another heavy wit, thought that Millerism should be included. After a short discussion, the bill was passed by a vote of eighty-nine yeas to eighty-three nays, the yeas having but a beggarly majority of six. Seventy-six of the eighty-nine affirmative votes were cast by members from the North, New York, Pennsylvania, Ohio, Connecticut, Maine and Massachusetts contributing the major part.

The bill was yet to pass the Senate, where opposition was strong. On the last day of the session, March 3, 1842, Morse spent the afternoon and evening in the Senate chamber. As the hours drew toward midnight, there seemed little chance of reaching his bill before

adjournment. Thoroughly disheartened by the prospect of failure, when success had almost been won, Morse retired to his hotel and arranged to leave Washington the following day. As he entered the breakfast room next morning, he was told that a young lady awaited him in the parlor. It was Miss Annie G. Ellsworth, daughter of the patent commissioner, who met him with smiling face.

"I have come to congratulate you," she said.

"Upon what?" asked Morse.

"Why, upon the passage of your bill, to be sure."

"You must be mistaken, for I left the Senate at a late hour and it then seemed certain that it would not be taken up."

"Indeed, I am not mistaken," replied Miss Ellsworth. "Father remained until the close of the session, and your bill was the very last that was acted upon. It was passed and I begged permission to convey the good news to you."

Almost overcome by his emotions of pleasure, Morse grasped her hand warmly and said, "For your reward, you shall send the first message over the line."

"I shall hold you to your promise — Remember!" she said in playful earnestness.

At this time Ezra Cornell, of New York, became associated with Professor Morse, and rendered valuable assistance in pushing forward the work of construction, which was begun at the Washington end. The first plan was the insulation of an underground wire by a sheathing of cotton, saturated with gum shellac, and its insertion in a leaden tube. After much labor, and the expenditure of many thousand dollars, this was found impracticable and was abandoned. Haste was necessary, for the time limit fixed in the bill had been nearly reached. It was determined to string the wire upon poles, with glass insulators at the points of contact, the plan being the same as that now in general use. The work was pushed with energy and the line between Washington and Baltimore was soon finished. During the progress of the enterprise, experimental messages were sent from time to time over the completed part of the line, and these dispelled all doubt of success. One of these messages conveyed to Washington the news of the nomination of Henry Clay for the presidency, by the Whig national convention, in session at Baltimore. The news was carried by railway train to the terminus of the finished line and there put upon the wire. When the messengers who had gone by the train reached Washington, they were greatly surprised to learn that the tidings had been correctly received by telegraph an hour earlier.

The line was in working order between the two cities by the end of April, 1844. It was clearly demonstrated, by many tests, that it

would fully meet all expectations. May 24 was appointed for a public exhibition and a formal opening of the first practical telegraph line in the world. The occasion was one of absorbing interest to scientific men, a large number of whom, from many points, assembled, some at Washington and others at Baltimore, to witness the trial and its result. The general public, attracted through curiosity, more than filled the chambers of the Supreme Court, to which the Washington end of the wire was conducted. Professor Vail had been stationed at the other end of the line, which terminated at Mount Clare, in Baltimore.

One may, perhaps, faintly imagine the intensity of emotion that filled the throbbing breast of Morse, as the moment drew near when he was to find the fruition of his hope — hope long deferred that had so often "made the heart sick." He did not forget his promise to Miss Ellsworth, and, when all was ready, she was summoned to the instrument. The words of the message were: "What hath God wrought!" selected by her, at the suggestion of her mother, from the Bible — Numbers xxiii: 23. Within the space of a minute, the words were returned from Baltimore by Mr. Vail. Success was perfect, and tears of joy streamed from the eyes of Morse as his friends crowded about him and overwhelmed him with congratulations. The strip of paper which bears the telegraphic characters of the first message was presented by Professor Morse to Congressman Seymour, of Connecticut, in token of his firm friendship and support, and is treasured in the Hartfort museum as a valued memento of the time.

Two days later, the Democratic national convention met in Baltimore and nominated as its candidates, James K. Polk, of Tennessee, for President, and Silas Wright, then a Senator from New York, for Vice-president. A telegram — to use the accepted word of later years — was immediately sent to Morse at Washington and by him conveyed to the Senate chamber. A few minutes later the convention at Baltimore was astonished beyond measure to receive a dispatch from Mr. Wright, declining the nomination. The delegates had not yet been able to grasp the idea of instantaneous communication between remote points, and they refused to accept the message as authentic. So incredulous were they, that they voted a recess until word could be received from Mr. Wright, by the slow method of the past, which, only, they believed to be trustworthy. It was the beginning of a revolution; the mark of a new epoch in the history of the world.

At its next session, Congress appropriated eight thousand dollars for the operation of the line, placing it under the supervision of the postmaster-general. The receipts for the first week varied from

twelve and a half cents to one dollar and thirty-two cents per day. Morse offered the patent to the government for one hundred thousand dollars. The subject was discussed in the report of the Postmaster-general, Mr. Cave Johnson, the witty gentleman who had proposed that one-half of the appropriation of thirty thousand dollars should be expended in the interest of Mesmerism. Albeit the experiment had succeeded to the admiration of mankind, Mr. Johnson, still incredulous, reported that the operation of the telegraph between Washington and Baltimore had not satisfied him that its revenue, under any rate of postage that could be adopted, would equal the expenditure, and the offer, fortunately for Morse, was rejected. Left to development by private enterprise, the telegraph became as familiar as the mail, and by many as commonly used. It has reached the remotest parts of the earth, and commerce and business are so adjusted to it that its destruction, if such a thing were possible, would be deemed a calamity too appalling to contemplate.

The Morse patent passed under the control of the Magnetic Telegraph Company, by which lines were rapidly extended in every direction. Great annoyance was suffered by reason of the attempts of other inventors and other construction companies to trench upon the rights of Morse. There were many infringements upon his patent, which led to long and vexatious lawsuits. At length, however, Morse's rights were upheld and protected by a decision of the Supreme Court of the United States. Thereafter, the system was developed with a rapidity that was marvelous. The Morse telegraph was adopted by the nations of Europe, and high honors were conferred upon its inventor.

The submarine telegraph cable, connecting America and Europe, followed. As early as 1842, Morse had experimented with a submerged wire between Castle Garden and Governor's Island, New York. The energetic efforts of Cyrus W. Field — backed by his own large means, and by other wealthy men whose confidence was inspired by that of Field — were at length rewarded after three costly attempts, covering a period of twelve years, and a cable was laid over the ocean's bed, uniting the two continents. Now almost every country in the world is touched by the magic wire.

In 1871 a bronze statue of Samuel F. B. Morse was erected in Central Park, New York. Upon it is engraved the first message that went, on that eventful day, from Washington to Baltimore. The unveiling of the statue was made the occasion of a great official and popular demonstration in honor of him whose work it commemorates. In the evening of that day, Morse was invited to meet the gentlemen who had formed the reception committee. By a concerted arrangement, all the wires in the United States were connected with an instrument in

the committee room. Professor Morse, amidst the loud acclaim of the company, sent greetings to the telegraphic fraternity everywhere. He struck the "sounder" with his name, when the operator added: "Thus the father of the telegraph bids farewell to his children." He was then eighty years of age.

The last public appearance of Morse was at the unveiling of a statue of Benjamin Franklin, in New York, in 1872. He asked, and was cordially given, the privilege of drawing the veil from the statue. At the close of his long life, he thought it fitting that he should perform this service, "for," he said, "the one conducted the lightning safely from the sky, the other conducted it beneath the ocean, from continent to continent; the one tamed the lightning, the other made it to minister to human needs and human progress." A few days later,—April, 1872,—Professor Morse was seized by a sudden illness and soon passed away.

During the latter half of the century, telegraphy in the United States has had a phenomenal growth. In 1867 the Western Union Company, the greatest telegraph corporation in the world, had 85,000 miles of wire and 2,500 offices. The number of messages handled was 6,000,000, and the gross receipts were $6,500,000 or about $1.05 per message. As the business expanded, the tolls decreased until the average amount now received by the Western Union is 31 cents. At present it operates 1,000,000 miles of wire; the number of offices has increased to 23,000, and during the year 1900 the company handled 63,000,000 messages, for which it received $24,758,000, leaving $6,165,000 as the profit of the year. This is exclusive of the business done by the Postal Telegraph Company, another strong corporation, and of the messages sent by cable to foreign countries.

Dead and forgotten are the narrow politicians who mocked and derided Morse. Dead and forgotten are the needy adventurers and greedy capitalists who sought to steal his well-earned laurels. Morse, too, has passed away, but every pole that bears aloft the shining strands of steel, bringing all the world into closer touch, is a monument to his work. His memory will be fresh and green so long as human hearts beat in sympathy with struggling genius, and courage, fortitude and character command the admiration of the world.

More than half a century has passed since Morse invented the telegraph, and the instruments used in transmission have greatly improved,

but it is a curious circumstance that his alphabet remains absolutely unchanged. Nothing superior to it has been found. It is as follows: —

A	B	C	D	E	F	G	H	I
. —	— . . .	. . .	— . .	.	. — .	— — .	. . . .	. .
J	K	L	M	N	O	P	Q	R
— . — .	— . —	———	— —	— .	. .	. . . . .	. . — .	. . .
S	T	U	V	W	X	Y	Z	&
. . .	—	. . —	. . . —	. — —	. — . .	. . . .	. . . .	. . . .

1	2	3	4	5	6	7
. — — .	. . — . .	. . . — .	. . . . —	— — —	. . . . . .	— — . .
8	9	0				
—	— . . —	———				

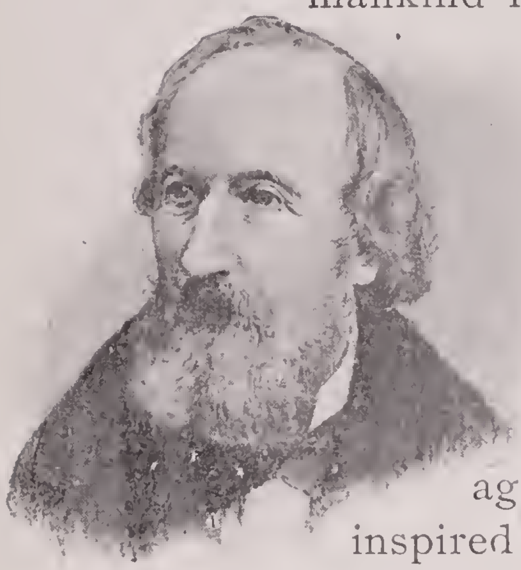
The English alphabet differs from the American in having no "space" letters; c, o, r, y and z being letters of that character. Space letters are the usual cause of telegraphic errors, for, if not carefully sent, they are easily mistaken for other letters. This will be seen by comparing the letters c and s. C is two dots, a space and a dot (.. .); s is three dots (...). Carelessly written, the letter c sounds exactly like s, and only experienced operators would know the difference. To avoid such errors, careful receiving operators copy a few words behind, and not close up to the sender. When characters are "blind," the context usually shows what is meant; yet not always.

It may interest the curious to know that, in manipulating the key, each operator has a style peculiar to himself. There is as much individuality in telegraphy as in penmanship, and one is as easily distinguished as the other. Some operators strike the letters so distinctly that their "sending" is, to the initiated, as plain as the words on this page. Others run the letters together with so little effort at legibility, that mistakes are to be prevented only by the receiver's vigilance. An operator seldom changes his style of "sending." Two men who had worked the same wire in America would telegraphically know each other, if they should suddenly "meet" on a wire in the wilds of Africa.

CYRUS WEST FIELD

Whose pluck gave to the world the Atlantic cable.

"I NEVER saw Cyrus so uneasy as when he was trying to keep still," was said of Cyrus W. Field by one of his brothers. This is an index to a leading trait in the character of one who made all mankind his debtor — one whom the world will not forget. Morse,



who invented the telegraph, first conceived the idea of a cable, laid upon the ocean's bed, through which messages might be flashed with the quickness of thought from one continent to another. But it was Field who grasped the idea as something real — something that the world needed, that could actually be done. His keen intelligence gave form to the enterprise, and his steadfast perseverance, in the face of difficulties and discouragements such as few men could face without flinching, inspired it with vigorous life. Twelve years he labored before success came. His pluck won the admiration of men; his hard-earned triumph commanded their willing homage.

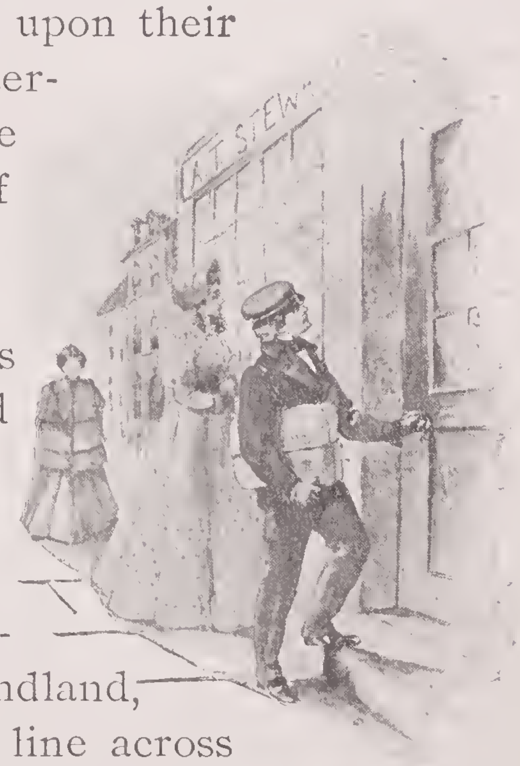
Cyrus W. Field was born at Stockbridge, Massachusetts, in 1819, and was a member of a distinguished family. He was a son of David Dudley Field, an eminent clergyman, whose father was Captain Timothy Field, a soldier of the Revolution. The brothers of Cyrus were David Dudley Field, a learned jurist of New York; Stephen J. Field, a justice of the United States Supreme Court; and Henry M. Field, a celebrated clergyman.

Cyrus was the only one of the four brothers who did not receive a college education. As a boy he was bright, active and restless, always impatient to be doing something. When his head and hands were not otherwise employed, they were pretty sure to be in mischief. It was his controlling desire to *do* that kept him from going to college; he felt that he could not spare the time. This habit of mind became even more marked when, as a man, he entered upon the activities of a busy life.

At fifteen young Field left home and went to New York to seek his fortune. His first employment was in the dry-goods store of A. T. Stewart, at fifty dollars a year. Very small wages, but it was a start that he wanted; he believed he could do the rest. Before he was of age he had gone into business for himself, as a manufacturer

of paper, and in a few years he became the head of a prosperous firm. Throughout his long life he was successful in whatever he undertook. When he made up his mind to do a thing, he dashed aside or surmounted every obstacle until his purpose was accomplished. He had large manufacturing and commercial interests which commanded his best efforts. These suffered during the years when his energies were diverted to the great project of his life. Partly in consequence of this, he passed through severe business reverses, which to many men would have been beyond retrieval. But when he fell, he was clever enough to "alight upon his feet," to use a popular phrase, and, without repining, he set his face toward the work of recovery. In his last years, however, when age had impaired his powers, a financial storm swept away his property and left him almost penniless.

On his return from a trip to South America, in the early fifties, he became interested in the momentous work with which his name will ever be linked in the history of great enterprises. By chance he met a citizen of Canada who had planned the laying of a telegraph cable between the island of Newfoundland and the main land. The project was to connect the cable with an overland telegraph line extending from New York, and thus anticipate by several days the news and important business communications brought from Europe by steamers, which touched first at Newfoundland upon their westward voyages. Financial aid was needed for the enterprise and Mr. Field was approached on the subject. He remembered that he had heard Mr. Morse express belief that an Atlantic cable to Europe was easily possible, and that sometime one would be laid. "Why not now?" said Mr. Field to himself. The question fixed itself upon his mind and his resolute will found the answer, "It can and shall be done."



Mr. Field had no difficulty in enlisting the aid of several wealthy and public-spirited men of New York, and a company was formed with Peter Cooper, the philanthropist, as its president. Mr. Field then went to Newfoundland, where he secured the necessary grant for the overland line across the island. Six hundred men were put upon the work of construction, for the route was through a dense forest, a distance of four hundred miles.

While this work was in progress, Mr. Field went to England — the first of more than a score of voyages which he made to Europe during twelve years of experiment and failure. He found ready ears in Great Britain — statesmen, scientists and men of business — to listen

to the details of the new and startling project. Some doubted, others declared it to be but the whim of a disordered brain, but there were many who believed in it, who gave to it their influence and later their financial support, and whose faith failed not until, after a long season of sore trial, the goal was reached.

Forty years later the genius and skill of American mechanics led the world, but at this time they had only just entered the field of scientific metal-working. It was, therefore, deemed necessary that the cable should be made in England. Mr. Field completed arrangements for this to be done, and included a short cable to be laid across the Gulf of St. Lawrence, to connect the sections of the overland portion of the line. In the construction of the cable, much had to be learned by experience. Those made during the costly experimental stage of the enterprise were too small, and lacked the strength to bear the strain of their own weight and the action of a stormy sea. It was to this that the repeated parting of the first cables was due. The short cable for the Gulf of St. Lawrence arrived in due time, but disaster came at the very outset. Forty miles had been paid out, when stress of weather made it necessary to cut the cable in order to save the vessel. Another cable, larger than the first, was afterward successfully laid.

While the work of making the long Atlantic cable was in progress, a survey was made of the ocean bed, by means of soundings, to find the most favorable route. The British government gave evidence of its interest in the project by offering the use of one of its vessels for that purpose. It was, of course, desirable that the shortest route be selected, and this was found to be between the west coast of Ireland and the eastern point of Newfoundland, both in British territory. The survey showed that this part of the ocean bed is a high and nearly level table of land, which extends nearly the entire distance. This is now known as the great telegraph plateau.

English capitalists were quick to become interested in the cable project and a company was formed with a capital stock of £350,000, of which Mr. Field subscribed one-fourth. The British government also gave hearty assurance of support. Lord Clarendon asked Mr. Field: "Suppose you make the attempt and fail — your cable lost in the sea — what then?" "Charge it to profit and loss and make another," was the ready reply. It had the "Yankee ring," and so pleased the Briton that he pledged his best efforts in behalf of the project, and continued its steadfast friend and supporter.

Mr. Field next returned to America and went to Washington to seek the aid of Congress. He did not ask financial assistance, but requested that the government should furnish one of its vessels to be used in laying the cable. A bill was drawn by William H. Seward, of New York, authorizing the use of a naval vessel for the purpose. It was entitled "An act to expedite telegraphic communication for the use of the government in its foreign intercourse." A letter from the New York, Newfoundland and London Telegraph Company was presented to Congress, in which were set forth the advantages that would result to the government and to the people. It stated that England would furnish a ship and urged that the United States do the same, "so that the glory of accomplishing what has been justly styled the crowning enterprise of the age, may be divided between the greatest and freest governments on the face of the globe." It is difficult, in these later years, to believe that opposition to the bill was so strong that it narrowly escaped defeat. In the House it had a safe majority of nineteen, but it passed the Senate by a single vote. It was approved by President Pierce, March 3, 1857, the day before his retirement from office.

Returning at once to England, Mr. Field found the cable nearly finished. The U. S. S. "Niagara" soon arrived, the cable was coiled on board, and the vessel sailed slowly away from the Irish coast, paying out the cable astern, while a multitude of people with loud huzzas bade the ship Godspeed. On the sixth day out, when three hundred and thirty-five miles had been laid, the cable parted. Mr. Field, who was on board, at once ordered the ship to return to England. While others were bewailing the misfortune, Mr. Field, who had no time for regrets, was arranging for sufficient new cable to replace that which had been lost. "We are going to try again!" he said.

For the second attempt, two vessels were employed, the "Niagara" and her Majesty's ship "Agamemnon." Half of the cable was placed on each and the vessels sailed in company to the midway point. The cable was spliced and the ships started in opposite directions. When a little more than a hundred miles had been paid out, the cable gave way and the ships were forced to return to England. Mr. Field was called to London to meet the directors of the company, some of whom had lost faith and favored an abandonment of the project. He, however, was undaunted, and his determination carried a majority with him.

The third attempt was briefly successful. The cable was laid and tests showed it to be in working order. The good tidings and the

interchange of messages electrified the people of the two continents. Queen Victoria and President Buchanan exchanged greetings of congratulation. The people celebrated the event with cannon, bands, bonfires, dinners and speeches. Mr. Field was overwhelmed with compliments and honors. But on the very day that the city of New York was paying him homage, the cable flashed for the last time and went to sleep forever. Again, while two nations mourned, Mr. Field went to work, with a courage that rose to the sublime. This time the entire cable had been lost. Would he be able to make another? At least he would try.

A new cable, much larger and more costly than either of the others, was prepared and stowed in the capacious hold of the "Great Eastern," the largest ship that had yet been built. Starting from Newfoundland, all went well until six hundred miles of cable had been run out, when there was another break. Efforts were made to grapple the severed cable, but in vain, and with sorrowing hearts on board, the big ship sailed to England.

A vast sum of money had been sunk and most of the stockholders of the company would pay no more. But at the magic inspiration of Field, a new company was formed and the work went forward. Again the cable was completed, and again the "Great Eastern" sailed upon her mission. The start was made on Friday, and the fact that this voyage was the triumphant one of the series, would seem to rebuke a popular superstition. On the twenty-seventh of July, 1866, the end of the cable was landed at Heart's Content, Ireland, and Mr. Field sent to his home across the sea this message:—

"Arrived here at nine o'clock this morning, all well. Thank God the cable is laid and is in perfect working order."

Once more there was a popular outburst of joy, and this time no disappointment followed. The history of human effort presents no more illustrious example of success nobly won by the patient, resolute pursuit of a lofty purpose.

Toward the close of his active life, Mr. Field wrote to a young friend the following advice, which may be read and remembered with profit:—

"Be brief, time is very valuable. Punctuality, honesty and brevity are the watchwords of life. Never write a long letter. A business man has not time to read it. If you have anything to say, be brief. There is no business so important that it can't be told on one sheet of paper. Brevity is a rare gift, and punctuality has made many a man's fortune. If you make an appointment, be sure and keep it and be on time; no man of business can afford to lose a moment in these busy times."

THE ELECTRICAL ENGINEER

By THOMAS COMMERFORD MARTIN
Editor of "The Electrical World," and Engineer

IT is at once admitted, by any one familiar with the development of electrical science and art, that few fields offer better opportunities in the future for young men, than electricity. The study of the nature of electricity has gone on since civilization began, but the practical industry dates only from yesterday,—not even from Franklin and Volta, but from Morse, Bell, and Edison. The first telegraph superintendent is still alive; the inventors of the electric lights are among us, hale and hearty; almost all the men, who have made the electric railway what it is, are hard at work in that or other branches. The earliest telephone patents have but just run out, and wireless telegraphy yet falters in sending messages across a few score miles of ocean. Recently, the writer mentioned to Edison that, at the new-century dinner of the American Institute of Electrical Engineers, one or two of the speakers had expressed the belief that all the great electrical inventing was completed in the nineteenth century, and that all this century would see, would be a development in quantity and degree of what had gone before. Edison regarded the mere thought as absurd, and said that, knowing what he now knows about electricity, he would like nothing better than to begin his own career at the present time. The trivial extent to which electricity has been pushed as an industry is, perhaps, realized only by those who have watched its growth for years. It is true that the active capitalization in electrical industries in the United States already reaches nearly $4,000,000,000; but, in view of what can be done, this is not a particularly impressive figure.

Large parts of this country know as little of the utilization of electricity as if they were in Central Africa. The American people send only about one telegram each, a year. Not ten per cent. of the mills and factories have electric power. Of the fifteen million families, not a million have a telephone. The vast majority of homes are without electric bells, or any of the other hundred and one contrivances which electricity offers for protecting property, communicating intelligence, economizing time, money, and labor. It may seem, at a cursory glance, that the trolley has become ubiquitous; but, although it is represented by $3,000,000,000 in capital, and some twelve hundred roads in America, it has

barely begun its work, and the investment in it grows heavily every year; while electric elevated roads and underground roads are constantly growing in number. Beyond this there lies, in the same field, telpherage, with its ability to transport mail and freight, in packages, along a thin wire or through a tube; and automobilism is usurping in modern cities the place and functions of the horse.

Of a truth, the electrical industry is "in its infancy," and the opportunities for finding in it an honorable and lucrative occupation are innumerable. If electricity never added to its present domain a single new art, it would abound in careers. The object of this article is to suggest where the openings may be found, how to get ready for them, and how to make the most of them.

The probability is that the youth who proposes to become an electrical engineer has but dim and vague ideas in regard to the subject. The glamour of some great and noble names is over him. He would invent a light, with Edison; a telephone, with Bell; welding, with Elihu Thomson; would harness Niagara, with Tesla; devise trolley cars and elevators, with Sprague; discover rays, with Roentgen; make diamonds, with Moissan; struggle with Moore for vacuum-tube lamps; or wrestle with Steinmetz over alternating-current problems. Should he feel the movings of financial or executive ability, he may want to handle great electrical manufacturing enterprises with Coffin, Barton, or Westinghouse; to put through huge street railway consolidations with the Whitneys and Everetts, or a lighting "deal" with Morgan or Brady; to organize a great submarine cable system with Mackay or Pender; to direct vast telegraph and telephone systems with Eckert, Chandler, or Hudson. He notes the names of these and other men, as he reads the newspapers or talks with electrical friends, and feels, as doubtless many do who scan these words, that he could do as they have done, if given the opportunity and the training.

There will not, however, be any attempt made here to discuss exhaustively the commercial side of electricity, it being safe to assume that the qualities that insure financial success in one field of business are pretty much the same as those which govern in the others. President Vreeland, of the Metropolitan Street Railway, for example, began his career on the Long Island Railroad. One of the most successful electric light station managers was an insurance man. The head of the biggest telephone system was a lawyer. The Niagara power enterprise was inaugurated by a banker, and a brilliant young legal associate. The pioneer transmission system, in the Far West mining regions, was fostered by a schoolmaster, and the head of the largest electrical publishing house in America was also a teacher. The chief electrical manufacturer in the United States was once proprietor of a Lynn shoe factory. The

novelty of the electrical art and the necessity of creating new productive resources, with new methods of marketing the goods, or of reaching out for export trade, as well as of organizing sub-companies in thousands of communities, have invited bold and skilful spirits.

To young men ambitious to reach the high places in the electrical profession,— the advice is earnestly given to be satisfied with nothing short of a technical education. In the earlier electrical days, this was not requisite, but it is now very necessary. The electrical army as a whole presents the curious spectacle of being led by self-made men, whose immediate staff and subordinates are nearly all graduates of prominent technical schools.

When the great outburst of electrical activity came, some twenty-five years ago, telegraphy was the only existing art that taught men anything about circuits, with the result that a great many operators, who were daring or ambitious, were presented with opportunities, that can only be compared with those in placer gold mining preceding the harder work of quartz crushing. Edison himself, once a train newsboy, did much to create fine careers for old associates at the key, many of whom are now wealthy and prominent men. So it was in the telephone field. One operator sold his Bell telephone rights in a leading city for less than $1,000. That city's exchange at present represents a capital of millions. But others, elsewhere, held on and now stand at the head of the art.

Nowadays, very few men are drawn from the telegraph field to fill responsible positions in electrical work, while telegraphy itself, as a career, has sadly shriveled up. It has some good prizes, of course, and they are usually taken by operators who began as messenger boys; but, for the great majority of the thirty or forty thousand men working at the key, the salary limit is only a few hundred dollars a year. Most of the work is mechanical routine of a rather wearing character; and women are rivals, too, getting the lighter tasks. Besides, there is always the likelihood of a development of mechanical, high speed telegraphy, which might create a few more executive positions, but would depress average wages, now none too good. It cannot be said that telegraph men view their position very hopefully, but there are two branches that have a brightening prospect. A great many cities have their fire and police telegraphs, and it is the tendency to magnify the office of superintendent by giving its incumbent care of all local wiring, and sometimes the control of a municipal lighting plant. So, too, on several of the steam railroads, the telegraph superintendent finds himself called upon to look after many things not dreamed of in his younger philosophy, and with increased responsibility comes higher pay. It is a fact, nevertheless, that this new work often taxes severely the ability of an official brought up on a meager scheme of Morse keys and crowfoot battery,

and the next generation of these men will all be much more highly educated and trained than are the worthy veterans of to-day.

Telephony is somewhat akin to telegraphy in offering restricted careers, yet it is still so under-developed that one hesitates to deprecate its opportunities. In both fields, valuable inventions will be made; it was but yesterday that Professor Pupin received a few hundred thousand dollars for his improvements in the carrying capacity of telephone circuits. For engineering work, however, there does not appear to be a large opening, although the telephone companies are far more liberal and enterprising in this respect than their predecessors of the telegraph have been. A large proportion of the work in any telephone exchange is done by women, as "hello girls" and monitors, while some exchanges are entirely conducted by women. Unless the exchange is a large one, there is no need of an electrical engineer, and the manager, with a little fundamental instruction and average intelligence, can keep things going.

In telephony, as in telegraphy, the future is with the educated man; it is very hard to find today, among those who have made telephone engineering a specialty, any one who is not a college graduate. It is obvious that, as the exchanges grow, the manager who is technically expert will often be in a very advantageous position. It is also obvious that telephone exchanges must inevitably form groups, and that these will centralize their engineering, thus minimizing the managerial responsibility and salary and leaving fewer well-paid employees. This has happened to some extent in the Bell system, and there are signs of it in what is known as the "independent" field. With some five thousand or six thousand telephone exchanges in the country, it will be readily understood that managerial salaries may range from small stipends to $10,000 a year; there are many engineering positions worth from $1,500 to $5,000. For the telephone rank and file, as with the telegraph, the situation is nearly hopeless. No earnest, ambitious man will be content to remain in it permanently. He can, however, use it as a stepping stone. The truth was summed up by J. P. Abernethy when he said, in his well-known book on commercial and railway telegraphy: "Telegraphing is the road to many excellent situations in railroad, express, and business circles." Andrew Carnegie long ago proved that statement to be sound.

Transferring the survey to the electric light and power industry, where current is generated by modern methods in huge quantities, and sold for an endless variety of uses from the street circuits, the two largest fields for electrical employment present themselves to notice. While telegraphy and telephony, kindred arts, represent perhaps $750,000,000, electric lighting and electric railways, kindred arts again, rep-

resent over $3,000,000,000, and their rate of growth is extremely rapid. It is in central station work that the best opportunities are offered in electric lighting, there being over 3,000 central plants. While the number of isolated plants is probably three or four times as many, they are not large, as a general rule, and are put in charge of licensed steam engineers. Such positions do not rise very high, usually, in either dignity or emolument. But central station operation involves clever engineering; and, while many men now engaged in it have grown up self-taught, the technically-trained man is the demand of the hour, and no other has much chance.

This is true of the management as well as of the engineering. One of the finest systems in this country, at Chicago, is ably conducted, at a munificent salary, by Samuel Insull, once stenographic private secretary to Thomas A. Edison. Another, in New York State, is carried on by a former Standard Oil broker, with equal efficiency; but both of these able men, as the problems before them enlarge, summon to their aid the best technical advice and support the country can afford. In such managerial and engineering work the pay is excellent, ranging anywhere from $1,200 up to $20,000 a year. In many cases, besides the salary, the manager or engineer has a direct interest in the plant, is given some of its stock as an incentive, or is allowed to subscribe for shares; and the instances are numerous of faithful, intelligent service thus being abundantly rewarded. This, of course, is more particularly true of the smaller stations, where responsibility is strictly personal. Such opportunities are constantly arising. In the larger cities, the work of consolidation that goes on everywhere has blotted out a great many independent competitive companies; but, on the whole, the cheapening of current and the extension of circuits has widened the area of employment and kept up the number and pay in managerial and technical positions. Young men are constantly called for to fill positions at small pay but with excellent openings ahead. The brighter and more studious of these make inventions or improvements, from time to time, that are sold for thousands of dollars.

Outside of the leading companies, there have grown up a great many consulting or contracting firms of engineers who find much to do in every city in planning and equipping plants for new buildings, etc. At the present time there is enormous extension of electric power to mills and factories, for which good electrical engineers are needed, either in constant attendance or for occasional supervision. Such work yields fair professional incomes, say from $2,500 a year up, to a great number of competent men.

In general, while the engineering of street railways has not been so complicated as that of central lighting systems, the magnitude of those

enterprises has made the field fully as promising and profitable to the electrical engineer. The management of many of these properties is still in the hands of those who started with horse railways and are untrained technically in the modern sense, but the staffs throughout consist largely of educated young men.

There are, in reality, only two ways of getting the education which will enable a young man to hold his own in the modern electrical world. One is the preferable way of taking a technical college course. The other is that of following the course of study provided by those useful institutions, the correspondence schools. To get into an electrical factory immediately after leaving an ordinary public or private school is a great mistake, although it is a good thing to supplement a college course with a year or two of factory work. Of course, there will always be geniuses who push to the front, like Van Depoele, the American trolley pioneer, who began life carving wooden images and reredoses in Belgium; or his compeer, J. C. Henry, who began at the telegraph key. But it is a question of training now for life-work, and in this respect too much insistence cannot be laid upon the thorough mental efficiency requisite. For those who cannot go to college, and are willing to study in their hours of release from daily duties, the lessons of some of the correspondence schools can be recommended. This plan may accompany work in an electrical factory, but the latter will be of little avail without it. Large manufacturing firms like the General Electric and Westinghouse Companies have students at their works, but they are all young men of education desiring to round out their theoretical knowledge by an acquaintance with practical design and construction.

In regard to what the college training in electrical engineering consists of, the four years' course at a certain prominent university may be cited as an example. Graduation after the complete course leads to the degree of E. E. — electrical engineer. The first year includes trigonometry, algebra, analytical geometry, physics, chemistry, qualitative analysis, descriptive geometry and drawing, and shop work. The second year includes the calculus, physics, physical laboratory work, industrial chemistry, quantitative analysis, properties of materials, elements of electrical engineering, engineering of power plants, graphics and drawing, and shop work. The third year includes analytical mechanics, resistance of materials, properties of materials, testing of materials, practice in the mechanical engineering laboratory, the steam-engine and its accessories, dynamo and motor practice, telegraph and telephone, direct-current laboratory work, electric lighting, dynamo and motor design, and the theory of dynamos and motors. The fourth year includes thermodynamics, heat and its applications, motor, dynamics of motors, machinery and mechanism, metallurgy, electro-chemistry, work in electrical engineer-

ing laboratories, electric power, the theory of alternator and transformer, electric railway, management of electrical plants, electrical distribution, theory of variable currents, advanced theory of electricity, theses, and original investigation or design.

This is a pretty complete bill of mental fare, and should yield good electrical engineers. Some men, who never ought to have taken up the study, drop out; some stay in, but are « duffers » to the end. Others feel the need of further study,—as, for instance, in the coming art of electrochemistry,—and go to Germany for it; or else go to France and study higher physics. Many young men now well known in electrical engineering have put themselves through college in a manner that commands admiration. Dr. Pupin, of old Slavic descent, now adjunct professor of mechanics at Columbia University, had little cash when he landed in America; but, even as a rubber-down in a Turkish bath, he devoted much attention to mathematical studies and inventions for which he is now so well known. The chief engineer of one of the largest electrical companies worked through college while a night telegraph operator in New York City. He is still a young man, but is on the council of the American Institute of Electrical Engineers, and has served two terms as president of the New York Electrical Society, the oldest body of the kind in America. Another electrical graduate, of Southern plantation stock, began his studies at Johns Hopkins University, but had to drop them. He became a motor inspector in New York, and then was appointed superintendent of a small suburban lighting plant, studying all the time. He was soon selected for the electrical professorship at a Western state university, and to-day is filling the same chair at the most important university in the Dominion of Canada. There is ambition displayed in these instances, and in many others which might be quoted, but assuredly there is also an underlying love of study and a courage that no obstacle can daunt.

ENLISTING IN THE ARMY OF THE TELEGRAPH

By JOHN B. TALTAVALL
Editor of "The Telegraph Age"

THE wide range of the telegraph business makes it an important industrial factor on this continent. Its opportunities for furnishing employment have been such as to lead to the creation of many special preparatory schools. There are no less than ninety thousand telegraph offices in the United States, Canada, and Mexico. Of this number, seventy-five thousand are in the United States. There are a million and a quarter miles of wire, four-fifths being in the states. A modern phase of the telegraph business in the United States is the gigantic proportions to which the leasing of wires has grown. These are used by brokers, bankers, newspaper proprietors, and commercial houses generally. It is estimated that there are at least one thousand such special wires in New York City alone. The special business of to-day is done in such a rush that it brooks not even the trifling delay of the general system. Firms and individuals find that having their own private wires so facilitates business as to warrant the additional cost.

The result of this is the employment of a great number of special operators. A private wire from New York to San Francisco costs as much as $1,000 per day, and requires operators of such expertness as to call for the highest pay. The Standard Oil Company owns and controls its own telegraph system, employing fully one thousand operators. The commercial and financial exchanges, and their members, control many thousand private wires, leading to all the principal cities of the country. Hundreds of operators are required in each line of business served in this way. The larger newspapers of the country often employ from thirty to forty operators on their private wires. Experts predict that this special branch of the industry will in time equal the amount of business done by the public telegraph offices, which amounts to one hundred and ten million messages a year.

Telephones are not making rapid inroads into the telegraph business, a popular impression to the contrary notwithstanding. The telegraph companies are taxed to their utmost capacity. As soon as a telegraph line is equipped to carry ten or fiften additional wires be-

tween New York and Chicago, there is an immediate demand for all the circuits to execute the ever-increasing business. It may be true that the telephone is absorbing some of the local business, but long distance telegrams are increasing in number so rapidly that the facilities are nearly exhausted, particularly in the construction department. For lack of space on the public highways to erect more poles, both the telegraph and telephone companies find it necessary to purchase land for the further erection of poles.

The qualification of a telegraph operator begins with a good general education. His spelling must be accurate, and he should be in touch with the topics of the day in order that he may intelligently follow the text of the matter submitted to him for transmission. He must have good health, an even disposition, common sense, a thorough mastery of the technic of telegraphy, an understanding of the uses of electricity in his vocation, the power to concentrate his attention upon his work, and fidelity to the interests of his employer. In the case of a woman, she must possess a certain amount of personal dignity, allied to tact and amiability. The variety of work handled gives the operator a keen insight into affairs of the world, political, business, and social. It also furnishes many opportunities for advancement. In fact, telegraphy rightly used, is a liberal education in itself. Scores of railroad presidents and managers have graduated from the key.

No employee gets a clearer insight into the complexities of railroading than the telegrapher, whose work touches all phases of it. Railway trains are run by telegraph, under the immediate control of dispatchers who must be expert operators. Train dispatching demands constant vigilance and a high order of professional skill. The dispatcher must know the road as a pilot knows the harbor. He must know the location of each siding and the number of cars it will hold; he must have a personal knowledge of the crew which each train carries; he must know the capacity of the engine and the extent of the grades and smooth stretches of track. At stations requiring but one man, the operator is also the railway agent, and he is the express agent as well, where the business is small. The duties merge easily into one another, and the pay averages nine hundred dollars a year, a fairly good income for such places. Beginning very modestly, perhaps, at a way station, he is at once in the line of promotion to more important relations and other higher duties. Whether he continues a train dispatcher all his life, or, after a few years of service, rises to the post of train-master, and thence to division superintendent, vice-president, or even president of the company, rests with himself. The prizes of railroading are awarded to the best man. To such rewards there is no royal road. The work demands a clear

head, shrewd foresight, and an ever-present sense of personal responsibility. Failure to deliver a train order, a misplaced switch, an incompetent or careless engineer — any of these things might cause an accident, and the killing and wounding of, perhaps, scores of people. Nor is this all, for besides the human sacrifice, there is the pecuniary compensation for personal injury or damage to property for which the company is liable, and the loss of rolling stock. These are some of the reasons why competent and responsible men are needed; when found they are not neglected. It follows, therefore, that promotions in this branch of the work are real rewards of merit, based upon the doctrine of "the survival of the fittest." All important railways follow the rule of filling higher positions from below. The cases are exceptional where men holding the higher offices have not been advanced from places of less remuneration, and often from the humblest beginnings.

In the early days of telegraphy, employment with the commercial companies, of which the Western Union and the Postal are modern instances, was preferred. The business was growing and skilled operators were scarce. During the Civil War the Government engaged scores of operators, at good salaries, for service with the armies. This increased the pay in large cities to as much as $110 to $125 a month. This high average continued for some years, until increasing competition, due largely to the employment of women, reduced it to $65 a month. In large offices, salaries as low as $35 a month may be paid, but expert operators, such as have been longest in service, still receive $80 to $90 a month. To chief operators, and to managers, $100 to $175 a month is paid.

An operator's work in a commercial office is confining and exhausting. True, the typewriter has simplified the work of receiving, as compared with the old method of copying with a pen, but modern appliances have not lightened the labor of sending, which, however, taxes the nervous system less than the work of receiving. The force in large commercial offices is divided into three shifts, one from eight a. m. until five p. m.; another from five until midnight, and a third which remains until morning, being then relieved by the regular day men. But those who work the night "trick," from five to twelve, are seldom relieved at midnight. It is oftener half past one, or two, or even later, before they are given the welcome "good-night." After midnight, however, they are paid for overtime, which increases the salary frequently to $100 a month.

In a large city office, the Western Union or Postal operator has few idle moments. If his wire be important, he is seldom out of his chair for so much as five minutes while in charge of it, and he must

be intelligent, quick-witted, and trustworthy. It is a mooted question if his pay is in just keeping with the requirements. Here promotions are rarer than in the railroad branch of the service, and usually are not above the position of chief operator, or manager, though many distinguished lawyers, financiers, journalists, and corporation managers, have received their start in the ranks of the profession. General Eckert, president of the Western Union; Albert B. Chandler, president of the Postal Telegraph Company; Thomas A. Edison, Andrew Carnegie, L. C. Weir, Senator Mantle, Thomas Oakes, Marvin Hewitt, David H. Bates, Edward Rosewater, Sir John Van Horne, J. J. Thomas, A. R. Brewer, J. G. Metcalfe, Milton H. Smith, Henry Clews, and the late Marshall Jewell, of President Grant's Cabinet, are but a few of the distinguished Americans in the list.

GREAT PROBLEMS OF INVENTION

By PARK BENJAMIN

It would be a difficult matter for anyone to define what a great problem of invention really is. I suppose it would mean a question the solution of which would result in some great and lasting benefit to the human race. But that definition presupposes that we can measure and compare benefits hereafter to be gained, which is manifestly impossible. We can tell what inventions have been of great utility to the world; but who can assign relative values to those yet to be made, seeing that they are infinite in number, and that, in the progress of the race, new ones arise daily, almost hourly?

Even if we regard each patent granted by the United States as requiring the solution of but one problem, then, in this country, we are solving six hundred original problems per week, and have solved nearly seven hundred thousand of them in the past. On these recorded solutions, nine-tenths of the industries of this country are now based. Naturally, there must have been many solutions of great problems among them to warrant this enormous investment of capital. But, if anyone attempted to designate the particular patents which contained such solutions, he would have an impossible task. Often they are discovered only after a long litigation. It was merely an extra twist of a barb which covered our continent with its present cobweb of wire fencing. Who could have perceived the invention of the speaking telephone, in a patent in which there is not a single word to the effect that the apparatus there described is capable of transmitting articulate speech?

It is seldom that anyone ever deliberately undertakes to solve a "great" problem. That the reverse is the case is the popular notion, which always imagines the typical inventor as a child of genius, with his eye fixed intently on nothing but "world forces," which, by some mystic power, he is about to harness for the use of man. It pictures him as disturbing the electrical charge of the entire earth, and thereby influencing the heavenly bodies in the outermost verge of space. The

practicability of his communication with the nearest planets is accepted with swift credulity. That he can evolve new sources of energy literally from nothing, seems entirely thinkable; and, no matter how extravagant the claims which he may make, or which interested parties more often make for him, there are always people ready to accept them as true, and to back their faith by substantial subscriptions of cash.

As a matter of fact, the real inventor almost always concerns himself with little advances. Frequently, he has no conception of what he has invented; and yet, contrary to public impression, he seldom gets his results by accident. He knows that he cannot make an invention by mathematical processes and the juggling of X from one side of a formula to another,—for that is the road which leads nowhere,—and equally well he knows that, if he goes star-gazing, and pays no attention to his path, he is likely to land only in the ditch. So, in the end, he learns to take short steps; and, if he be wise, the only hope which he will permit himself is that some day some one of these will prove to be the last one necessary to reach the goal. Thus it comes about that successful invention is not the result of a constant reaching after the present unattainable, which always stands postulated as a great and alluring problem; but it is in reality, the making of short advances, one after another, perhaps through many generations, until, at last, just as the coral reef is built up cell by cell from the bottom of the ocean, until it finally appears above the surface, an invention is perfected by small and gradual accretions, and the work of the particular man who brings it to light is only the last addition,—the apex which crowns the heaped-together labors of numbers of men, without which his own would have no support.

Why these steps, great or little, are ever taken, is in itself an unsolved problem. Whether a man of unusual inventive genius is a product or a factor of the circumstances about him, is always debatable. We may believe, with Emerson, that souls are born out of time, —extraordinary, prophetic,—who are rather related to the system of the world than to their particular age or locality; or, contrariwise, with Froude, that even the highest genius is never more than the highest degree of excellence which forms the environment. Is invention inspiration, or merely the reflex excitement of a brain impressionable to certain surrounding influences? The patent laws of this country are ultimately based on the first conception; yet, as a matter of fact, nearly all inventive acts are probably due to what is no more than the mental resonance of preëxisting and environing ideas,—the novelty lying, so to speak, in the composite tone or chord emitted and not in the fundamental note.

The length of time which an invention takes to fructify or develop has but an obscure relation to the general problem. Some ideas remain, after their first appearance, inchoate for ages; others, evolved in the meantime, rapidly grow to perfection. The problem of aerial flight, the study of which began centuries ago, is still unsolved. So is the economical utilization of the tides, and the direct employment of the sun's heat to generate power cheaply, which are riddles almost as old as the race. The steam turbine, now coming into practical use, was first described nearly three hundred years ago; the electric light waited almost two centuries for general utilization; and the electric railway, over eighty years. On the other hand, the electric telegraph was in successful operation within fifty years after it was first suggested, and the telephone in less than a decade became a necessity of life.

Nor is it merely the broad and general conception which alone lies idle and unimproved. Ideas which, it would seem, should be at once turned to practical account, suffer the same paralysis.

Light produced by an electric discharge in a vacuum globe was discovered by Hauksbee in 1709. It is only within the last ten years that attempts have been made to adapt this mode of illumination to practical purposes. The latest form of electric lamp which, many believe, will replace the familiar carbon filament bulb, is simply an exposed rod of porcelain, magnesium, or other insulating material that is a non-conductor when cold, but which, when sufficiently heated, allows the current to pass and then bursts into glow. It requires no vacuum around it, and it is believed to be far more economical than the filament lamp. It was invented by Jablochkoff in 1876, when everybody was trying to adapt the blinding electric arc to the uses of general illumination. It was one of the first notions of the employment of a glowing mass in place of the dazzling flame. But then the filament came along, and all the world forgot Jablochkoff's luminous porcelain, until about four years ago, when a German professor reinvented it; and now, by an odd irony of fate and the connivance of its promoters, it is known by his name and not by that of the man who really made the discovery.

The history of the automobile is even more striking, as affording an instance of long delay. Instead of being a new departure in locomotion, its practical, every-day employment antedates steam railways. Oliver Evans, of Philadelphia,— the universal genius of his day,— had one in 1786 which was actuated by steam to run on wheels on the land, and to be propelled by paddles in the water. Subsequently, he removed the paddles and devoted himself to the promotion of the land vehicle. Because of this the Pennsylvania legislature solemnly said

he was insane, and the lawgivers of Maryland gave him a patent on the wagon, only upon the argument that "the grant could injure no one." Trevithick, in England, had a steam automobile in 1804, but gave it up because of the badness of the roads. Then the idea slumbered, the inventors mainly turning to railways,— until Gurney, in 1825, devised a steam carriage which, six years later, became a regular public conveyance on the ordinary turnpike roads between Gloucester and Cheltenham.

The carriages ran four times a day for four months, and carried nearly three thousand people over an aggregate distance of four thousand miles; making the individual trip of nine miles in about fifty-five minutes. They were driven out of existence by the populace. Country gentlemen, trustees of roads, farmers, coach proprietors, coachmen, and even the post-boys united against them. Some said they would be injurious to agriculture, others that they would injure the roads, others that the non-use of horses would destroy the market for oats and this would ruin the farmers, and the coach owners, loudest of all, bewailed the competition with their business. In vain it was pointed out that such quick transportation would immensely benefit the community, that eight people could live off the land required to support one horse, that only half the fare demanded by the regular coaches was charged, and that the roads would be less hurt by the broad-wheel rims of the automobiles than by the narrow tires of the coaches. Stones were heaped up in the roads so that the vehicles were wrecked, and the final quietus was given in the form of turnpike bills enacted by parliament, to impose prohibitory tolls on what an honorable member called the "steamboats on wheels."

Then came Stephenson and his railroad, the latter growing into the great network of tracks which now covers the globe. Meanwhile, for sixty years, the horseless vehicle lay practically dormant. When it was revived, the same old questions about it which agitated the grandfathers of the present generation came up again. Will it climb a hill? Can it be made smokeless? How is water to be carried?— and so on. Of course, the invention of the storage battery has rendered electric propulsion possible, though at the heavy cost of devoting half the available power to the moving of the weight of the battery itself. The gas engine, burning vaporized petroleum, has replaced the engine of seventy years ago, driven by compressed gas. But the steam automobile of to-day, in some respects, is not as far advanced in its construction as was the old steam carriage. There is not an automobile yet in existence which is not fairly clamoring for new inventions to bring it to the proper status of a cheap, safe, and comfortable conveyance.

On the other hand, the bicycle, propelled by foot treadles, begun as late as 1864, created a little *furore* in the form of the old "bone-breaker" of 1870,—and, after developing into the lofty huge wheeled "ordinary" of the 'eighties, seemed to have reached its culmination. But then came the reinvention of the pneumatic tire, and the introduction of ball bearings. The tire was old and had appeared in England in 1847, when it was made of canvas and leather. The rubber industry had grown meanwhile, and solid rubber tires had already been placed on the wheel rims of velocipedes. These changed into arched or cushion tires, and then the inventors went back to the pneumatic or air-filled tire, and proceeded to devise ways of fastening it on the rims. Coincidently, the form of the machine shrank to the low "safety," and speed was obtained by gearing instead of by directly applied cranks. In ten years the whole apparatus changed from a toy to a vehicle for every-day use, brought to such a stage of perfection that, at the present time, it would be difficult even to suggest the future trend of improvement in it.

Frequently, however, a great problem is conquered by the happy adaptation of an idea, already known, to a new purpose. For example, in 1885, Marcel Deprez conceived the notion that a rotating magnetic field might be produced by the combination at right angles of two alternating electric currents, which differed from one another by a quarter period in phase. Three years later, Tesla saw the possibility of producing a rotary field in an electric motor in this way, and demonstrated it, and for the first time constructed the apparatus, which subsequently rendered practicable the harnessing of Niagara.

As has been said, it is exceedingly seldom that any great problem is solved by accident. I can recall no striking modern instance of this except that of the telephone, which Alexander Graham Bell says "opened in his hand," and was in fact due to the chance observation of a wholly unexpected effect in apparatus not devised for the purpose. Mr. Edison certainly has courted chance, and years ago equipped a laboratory with "every known substance" (as his critics averred), with the intention of trying what everything would do when mixed with everything else; but his productions of late years show no indications of the fortuitous, and, in fact, are rather typical than otherwise of the "little step" beyond the accomplishments of others. If there be any specially recognizable modern tendency, it is not to depend at all upon opportunity, and even to attack a problem through a comparison of abstract possibilities and processes of mathematical elimination of factors. Professor Pupin's recent discoveries in telegraphic and telephonic transmission were not merely the results of inventive conception, but of the merciless tracking of it by mathe-

matical tests continued over many years,—a course which it would have been impossible to follow had he been a less profound mathematician than he is. The net result is the possible substitution of steel for copper wire on long telephonic circuits, at an immense saving in cost, a great increase in the distance over which telephonic communication can be economically sold, and a lively expectation tha the problem of talking across the ocean is no longer insuperable.

There would be little difficulty in multiplying instances to show either that the times are often ahead of the man, or the man ahead of the times,—either that the idea exists and no one is impressionable, or that some one has formed the impression and there is no environment suited to receive it. But, in the end, debate the question as we may, every successful invention ciphers down to a product of man and times, both co-acting as necessary factors.

While the discernment of a great problem is in itself a certain advantage toward its solution,—and the clearer the discernment, the longer is that step,—still the actual crossing of the gulf alone can result in achievement. Finger posts are useful to point the way, but they get nowhere. Conceptions of how one would like to overcome the barrier, or how one thinks it could be done, or ought to be done, are often mistaken for doing so; though not so frequently nowadays as fifty—nay, twenty-five—years ago, for people have learned to their cost that claims do not necessarily imply accomplishment, and there is no title more easily gained by a little humbug than that of a "modern wizard."

The problems of invention are almost infinite in number, and impossible of comparison;—and yet it is not difficult to single out the one which is greatest of them all. That is the chemical combination of carbon with the oxygen of the air, without the production of heat, and, as a consequence, with the production of electricity. When this is accomplished, we shall obtain our power, not with a loss of ninety per cent. of the energy stored in the fuel,—which is the condition of the steam-engine and boiler burning coal,—but with perhaps less than ten per cent. loss. That means not only the end of the reign of steam, but power so cheap and universal that no mind can fathom the capabilities of the race after the accomplishment shall have been made.

As to what are the problems next in order of importance, few will agree; but probably they are, first, the economical isolation of the nitrogen of the air, which will permit the production of artificial fertilizers, at a cost which will force Mother Earth to bring forth her increase at a rate now scarcely thinkable; and, secondly, the direct utilization of solar heat to make the sun pump water to irrigate

the deserts and dry places of the earth and fit them for human habitation.

But, meanwhile, there are many minor problems — minor only in their relative sense to those vast ones — urgently pressing for solution — and some are very close to it. We want to know how the glowworm makes light without heat, — and how to do it ourselves; — how to make the high potential alternating current drive all the locomotives; how to construct an unsinkable ship; how to telegraph by the etheric waves without possibility of interference by disturbances in the same medium; how to extract solids from liquids economically by centrifugal force only [Since the above was written the Gathman water purifier has been invented. — Editor.] and not by filtration; how to adapt the steam turbine as a motor to every-day uses in place of the reciprocating engine; how to build a cotton-picker as effective in gathering cotton as the reaper and mower are in gathering grain and hay; how to photograph in the colors of nature; how to throw high explosives with safety from ordinary guns. But why continue a list which every one can make for himself differently, as he looks around his individual horizon? We may be certain that, upon every problem that is now recognized, intelligent thought is at work. The gems are hidden in the ocean depths.

HOW TO SUCCEED AS AN INVENTOR

By THOMAS A. EDISON

THE young man who wishes to succeed as an inventor should never lose sight of the fact that nearly all great inventions are the results of logical and carefully made deductions from natural laws. Those which are the outcome of accident or chance are such rare exceptions that they confirm the general rule. In my own labors I have always had some well-defined object in view, and the great majority of my inventions are the result of patient labor and of experiments often continued for years. For instance, the automatic recorder prompted the automatic repeating telegraph, and the latter, in after years, led to the phonograph. It was in 1877 that I finally succeeded in perfecting an instrument which recorded telegrams by indenting a strip of paper with dots and dashes, and also repeated a message any number of times and at any rate of speed desired. Now, as a logical sequence, it occurred to me that if the repeater would again give forth the click of the telegraph instrument, the vibrations of a diaphragm should also be susceptible to similar record and reproduction, and I at once began the series of experiments which led to the phonograph.

The electric light is another illustration of my theory of invention. None of my inventions has cost me so much time, labor and study as did that; and though I, myself, never lost hope of ultimate success, some of my associates were often discouraged and despondent. I would frame a theory and follow it up until I found it did not conform to the facts at my command, when I would discard it and construct another that for the moment seemed to answer the purpose. Thus I evolved three thousand different theories before I finally secured that for which I was seeking, and confirmed the principle upon which I had been acting from the first. During this time I read hundreds of books bearing upon the subject, but the aid I secured from this quarter was small; indeed, I am seldom able to find what I want in books. To secure the best material for the carbon filament used in the light, my agents ransacked all parts of the globe, and it was not until a hundred other things had been tried and found wanting that the shred of bamboo now employed was settled upon. Patience and continuance are indispensable to the successful inventor.

He should also be a capable man of affairs. Many of my own inventions have been very profitable, but I have made money as a manufacturer and not as an inventor. I would have been a gainer if I had never taken out a patent, and, in most cases, my advice to the young inventor would be to refrain from doing so. A certain mechanical operation may require the time and labor of forty men, but some clever fellow invents a machine that will do it with the help of only one man. As long as he keeps the machine to himself, he will have a monopoly of the market; but if he takes out a patent, in nine cases out of ten his idea will be stolen, and as soon as his rival secures a similar machine, his invention will have lost its value. As a matter of fact, many of the most valuable inventions have never been patented, and are kept as secret processes. Stub steel is used all over the world for making certain kinds of fine springs, and yet there are only two or three people now living who know how it is produced. It is made by an English family, and the secret has been handed down from generation to generation for nearly two hundred years. The holders of the secret have made a fortune from it. Sealskins are dyed at only one place in the world — London. The secret was discovered by a Vermont man, who carried it to England, and the process has been kept there ever since. Thousands have been expended in experiments, but no one has yet been able to successfully imitate it. I could mention many other products in common use whose manufacture is a secret, one workman knowing only one part of the process, and not the whole of it, as a rule. Most of these products are made in Europe, like Chartreuse, the secret of which is kept by the monks at the monastery of that name, where the liquor is made. But the practice of keeping processes of manufacture secret is growing in this country. Strangers are denied admission to many of our largest factories for fear of some secret process leaking out, and the workmen are sworn not to divulge the facts. The Dupont powder works, on the Brandywine, is a striking example of this policy of secrecy as practised in America. The Duponts have rarely if ever taken out patents on any of their processes, but hand them down from father to son, and the workman who enters their employ usually remains with them as long as he lives.

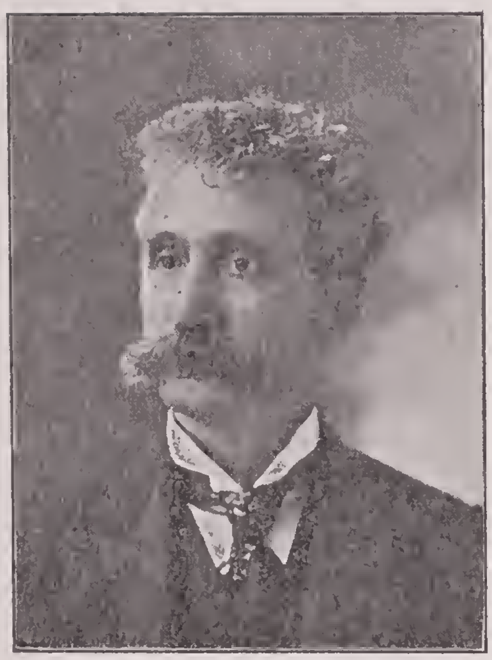
The inventions which under present conditions are making the most money are not the big but the small ones. Their insignificance protects them from the pirate, who fails to discover that there is money to be made by stealing them. Still, my advice to a young inventor would be to study the expensive operations of all large factories — every operation, you know, is expensive in proportion to the number of men required — and try to devise a machine with which fewer men could do the work. The wealth of the modern world has been made by labor-saving machinery; but no matter how fast it may be increased or how often it may be

multiplied, there will always be plenty of work for all, for the workmen set free by the invention of a new labor-saving machine soon find employment in some other field of usefulness. Wealth is the product of labor, and the machine that saves the latter also saves the former, and adds to the general sum of wealth. Thanks to machinery, as much wealth is now produced and saved in a single year as was formerly produced in a century, and by the same means the United States has caught up with and passed the older countries of Europe. A few years ago steel rails cost $125 a ton. Now a manufacturer brings two pounds of ore from Lake Superior to Pittsburg, a pound of coal from the mines of the Monongahela Valley, a pound of manganese from the South, and a pound of another ore from the West, and with these he makes a pound of steel and sells it for a fraction of a cent. This shows what labor-saving machinery can do. The end has not yet been reached in this field, and it is still possible for a young inventor to devise a machine for some operation essential to the manufacture of steel which would save the labor of a number of men. Then if he went into the manufacture of that one product on his own account, he could hold his own with all the other manufacturers and undersell them as long as he kept the machine a secret. There is no better method by which the inventor in these days can get the full benefit of his invention.

What will be the general tendency of invention in the near future? That is a question which no one can answer with certainty, but I think for many years to come, invention will deal in the main with securing greater economy of motive power. The turning of coal into motive power without the intervention of steam will be one of the next great triumphs of the inventor. I have for some years been at work on the problem of turning coal directly into electricity. I have clearly demonstrated that this can be done, and it now remains to be seen if it can be done at a profit. It would be a great thing if we could run a steamship or locomotive for one-sixth of what it now costs, and I believe it can be done. Let me add that machinery is settling the labor question, and in favor of the laborer, who is every day becoming worthier of his hire. The multiplication of machinery in the last fifty years has doubled wages, while reducing the cost of living one-half. When motive power is still further cheapened, the laborer will be master of his own destiny, and the labor question will cease to exist.

INVENTION AND ITS RELATION TO WAR

By HUDSON MAXIM
The Inventor of Smokeless Powder and Maximite



No man can have greater power of prophecy than is based on accurate knowledge and understanding of past events and their tendencies. We can judge only of man's future work from what is foreshadowed by past achievements.

It is a far reach from the cluster of dens and caves of the Paleolithic savage to the civilized home and the modern city. Man's tastes were then simple and his needs few. His passions and appetites were strong, and when sated he lay dormant until again stung to activity by their return. He understood nothing of the nature of the forces that brought the recurrent seasons, nothing of the sunshine, nothing of its eclipse, or why the tempest blew. He cowered at the tongues of fire that spoke with thunder voice in the storm. The rivulet sang then as now, but to him its voice was not a song. The river rushed and foamed across his path in its descent to the sea, but he understood nothing of the source of those waters — how the sun lifted them from the earth and ocean, to fall again in rain and give the sap of life to all the bloom and green of field and forest.

It required long centuries for the dull brain and the unaccustomed hand to shape the simple stone hatchet and the arrowhead of flint or bone. The first architect who made his habitation of logs and boughs was indeed an inventive genius of his time. Impelled by his powerful passions, appetites, and needs, man has, through the ages, been grappling with the forces of nature to understand and conquer them to his use. The youth of to-day, endowed with the rich inheritance of ages of accumulated knowledge, with capacity to wield and utilize that knowledge, is possessed of might to shame the fabled gods of antiquity.

We learn the complex from the simple. We can only arrive at the abstract by way of the concrete. It is easy to understand how man's first needs impelled him to construct implements to aid him in the acquisition of the necessaries of life, to enable him better to battle with the fierce denizens of the forest and bring them to his feet for food, and give him their own covering for clothes, or to defend his humble home against his still fiercer fellow-kind. That was the dawn of mechanics. His implements, simple as they were, marked a vastly greater stride in

human advancement than all the achievements of the nineteenth century. Long ages were required to replace the stone with bronze, and ages again before the bronze was replaced by steel. Then intervened the Middle Ages of superstition; it has been less than a hundred years since the white man burst from the chrysalis wherein he had been caged by fear. It is but recently that he dared reach out and grapple with all of nature's forces without fear to understand or fear of profanation; and now the scientific inventive man recognizes all nature as the rightful field for his operations, investigations, and conquests.

When the great ice sheet had melted from the face of Europe, in recent geological years, the new opportunities presented by the changed condition had upon our race a character-building effect, adapting it to the great possibilities of the present era. The closing of the glacial epoch was a great geological springtime — a period of rejuvenescence, when, with the expansion of land areas and all the concomitant opportunities, man's mentality was also expanded. As environment shapes the character of the individual, so it affects the race. The quick eye, upon which security depended in the remote past; the strong arm with which to strike for food or life; the awakened sense, trained in battling with the wild beasts of the forest and with yet more savage men — were all builders of that brain which now builds the locomotive within an ark of safety, defies the ocean's hurricane, harnesses the lightning in the service of man, and brings the whole earth within touch of the family.

The discovery of America, with the mingling of races under changed conditions of life — in a new world offering greater resources and possibilities, above all, greater freedom — has made almost a new race of men; a race having a more independent way of thinking, one reasoning more from experience and less from theory and dogma — a race more resourceful, active, and determined. The greatest influences to break the chrysalis of medieval superstition and clear the mind for action have been exerted by Americans. Braver than those they left behind, a daring few who placed themselves on the bleak New England coast — with the great ocean behind and the unbroken forest, filled with savages, before — were of the right spirit, and in a suitable environment, to pioneer a strong and inventive race. The substance that could be grubbed from the barren soil in the brief summer was not sufficient for the long winter, without recourse to every expedient that human ingenuity could devise. Stern necessity was then, indeed, the mother of invention.

A few generations have swept away the wilderness and the Indians. Workshops and factories dot all the waterways, where is produced every conceivable thing, mechanical and scientific, demanded by our civilization. Labor found honor in New England, where inventive genius

brought both praise and reward. As a result of these genius-building conditions, America has produced probably more than seventy-five per cent. of the inventors and inventions that have revolutionized life. New Englanders and their descendants, multiplied and scattered throughout America and over all the earth, have led and still lead the inventive genius of the world. But for the inventor, we should all be running wild in the forest, clothed with leaves and the skins of beasts. It is the inventor who has taken man out of caves and hovels and placed him in mansions; who has developed every convenience and every luxury of modern life; who has made this earth a fit abode for something better than simple savages.

Truly, « Necessity is the mother of invention.» Without needs there can be no progress. Labor is the great factor formative of genius. Love of labor is indicative of true genius. It is an unvarying rule that love is an accompaniment of capacity, because of the pleasure in the exercise of strong faculties. Capacity for work and a disposition for usefulness are inseparable concomitants of happiness. Those animals are the most intelligent which are endowed with the best faculties for the examination of things, and man is no exception. The thumb has been an important factor in the development of mental faculty, which, in turn has made of the human hand the most wonderful of instruments.

The complex conditions of civilized life are constantly forcing upon us new capacities for usefulness. As these conditions become more and more exacting, we are all required, in one respect or another, to be geniuses — although universality of genius becomes impossible by reason of limitations of time, attention, and endurance. Civilization demands that labor be divided and functions specialized. Love for the work in hand is the mother of its success.

Intellectual acuteness is always much in proportion to necessity. A young man may well console himself in poverty, for it may prove a greater aid to true success than the wealth of Crœsus. The peoples of the northern nations who have had to contend with the winter's cold, and to war with the wolf of hunger through the long months of frost, are far superior intellectually to the inhabitants of tropic climes. With the increase of necessity, the alertness and sagacity of the individual, who must meet the changed conditions, is also increased, else he must perish. Such is the history of the race. It is obvious that nothing could so stimulate man to effort, and to the exercise of inventive faculties, as war, calling for the defense of life and home on the one hand, and offering on the other the coveted rewards of conquest.

The fighting instinct has, perhaps, been the ruling trait of our race from remote antiquity, where fact blends with fable. The sun of civilization's dawn broke through a war cloud, and the light it has since shed

on mankind has shone through rifts in clouds of war. The inventive and fighting instincts have made ours the dominating race. These are the instincts that have cleared the land of forests, spread industries and civilization over vast continents, and united them with ties of trade, reducing the ocean to a ferry.

It is natural, then, that the field of Mars should offer especial opportunities to inventors. No branch of industry has played so great a part in the civilization and enlightenment of mankind as has the development of implements of war. Without the stimulus afforded by the constant menace of neighboring powers, a nation may allow its arts and sciences to remain stationary, as China has done for the last thousand years. Stimulated by the menace of war, however, all this is changed, and the ingenuity of the people is taxed to its utmost to meet the peril.

The discovery and introduction of gunpowder called for a complete revolution in all military implements and operations. Since then, improvements in weapons have kept pace with improvements in gunpowder, and all the industrial arts have been affected and benefited.

In "Sartor Resartus" Carlyle says: "The first ground handful of Niter, Sulphur, and Charcoal, drove Monk Schwartz's pestle through the ceiling. What will the last do?" His own answer is: "It will achieve the final undisputed prostration of Force under Thought, of Animal Courage under Spiritual."

Again Carlyle says, in the same work: —

> "Such I hold to be the genuine use of Gunpowder: that it makes all men alike tall. Nay, if thou be cooler, cleverer than I, if thou have more Mind, though all but no Body whatever, then canst thou kill me first, and art the taller. Hereby, at last, is the Goliath powerless, and the David resistless; savage Animalism is nothing, inventive Spiritualism is all."

The debt which civilization owes to gunpowder is one of the greatest that history has to record. In every land, and upon every sea, gunpowder stands guardian over all the accumulated wealth and progress of the nations. The development and perfection of gunpowder has tasked the genius of the world for a thousand years, culminating in the production and perfection of the smokeless cannon powder of the present time, at the head of which, that adopted by the United States Government unquestionably stands. The harnessing of that energy which now can hurl a half-ton bolt of steel through three feet of solid iron has been a giant task. The modern high-power gun in its building has reacted with immense advantage as a developer and builder of the arts and sciences.

The modern battleship is to coming generations a lesson of the nineteenth century. The implements of war invented during the last hundred years will serve to write on history's page more clearly than those of

any other branch of human effort the story of the world's work. The earth-jarring thunder of the seacoast gun — the hum of the great steel bolt as it speeds along its way — the crash into the toughened steel ribs of the battleship — are all voices that speak of the high development in the arts and sciences of this inventive age of which chemistry is king. Electricity, steam, and gunpowder, are the great Triumvirs that have been the architects of the modern world, and the pillars of the whole structure rest on chemistry.

When we compare the present position of military science with that at the opening of the nineteenth century, the strides are truly marvelous. We of the last century received from our fathers the flint-lock gun loaded at the muzzle by means of a ramrod, with powder, wad, and ball, carried separately. The artillery we received was a cast-iron tube, a bag of pulverulent black gunpowder, and a round, solid, cast-iron shot. The soldier slept in the field, with nothing over him but a blanket and the sky. The battleship of our fathers was a rude, wooden hulk, which crept about under sails, and was the victim of the freaks of the wind and the sea. It was lighted at night by the tallow candle, or by an ignited rag or torch fed from a bath of grease. All that was known of the whole science of chemistry could then have been told in an evening's lecture, while electricity was only a curiosity. These were the conditions that prevailed a hundred years ago. We now have the breech-loading magazine rifle and smokeless powder, the machine gun, with its stream of one thousand bullets a minute, and breech-loading rapid-fire artillery, capable of hurling such a storm of shrapnel and canister as to render it as impossible for an enemy to advance through the open and not be struck as it would for one to pass through a thundershower and not be hit by a raindrop.

The children of the nineteenth century have harnessed many of the agencies of nature, but the most marvelous of all has been the impressment into man's service of that most subtle of all — electricity. It is quite impossible for a person reared at the present time to appreciate what life would be without electric cars, the electric light, the telephone, and the telegraph.

Nowhere are electrical inventions more indispensable to-day than in naval and military science. Armies reconnoiter under the guidance of the telegraph. They can advance no faster than wires are laid and telegraphic communications established. The balloon, which gives a vantage view from the sky, can be spoken through a wire by the commanding officer in the field. Electricity has taught the artillerist the exact velocity of his projectiles, and how far his gun will carry.

Let us assume the existence of war, and imagine ourselves aboard a battleship, where the searchlight — that keen electric eye — penetrating

the night in defiance of the storm, is an ever-watchful sentinel at the post of danger. A small torpedo craft is sighted, advancing with hurricane speed, armed with its submarine messenger of death and destruction, one blow of which, and our huge steel leviathan — worth a king's ransom — with its thousand souls on board, is sent to the bottom of the sea. But the electric eye has seen it — the searchlight rests upon it — and it looms up, a brilliant target in the night, while hundreds of shot and shell are hurled within the space of a minute upon that brilliant spot, and it is destroyed. Still the long bars of light sweep the horizon, and there is a dark mass discovered, advancing at almost railroad speed. It is a battleship of the enemy, the sea is heavy and our ship is rolling; our guns are ponderous and but little deflection will make them miss their mark, but they have been provided with electrical training gear. A huge tube of steel weighing fifty tons is controlled by the gunner with the ease of a child handling a toy, and with the quickness with which a rifle may be raised to the shoulder, aim taken, and the trigger pulled, the big gun is sighted at the advancing stranger. There is a flash, a roar like thunder. The recoil shakes the giant warship to her center. But a huge bolt of steel weighing one thousand pounds charged with Maximite, is hurled at the enemy. It strikes her mailed side — it passes through. There is a terrific explosion within her vital parts, and our danger for the time is past.

The importance of high explosives as a factor of our modern civilization, in peace as well as in war, is not fully appreciated by the multitude. The invention of dynamite by Nobel placed in the hands of the civil engineer a new force ten times more powerful than gunpowder, and his work has been correspondingly facilitated and accelerated. As the ax is to the woodman, so are high explosives to the civil engineer — more, they are the ax and the spade with which he cleaves the mountain range to let the iron horse pass, and like the Martian, cuts through the land a webwork of canals and waterways, uniting rivers and seas. With high explosives he smites the rugged ribs of the earth, and the yield of a day in mineral wealth would shame Solomon in his glory. Since the time when the great Hannibal with fire and vinegar cut through the white Alps, and burst like an avalanche upon the fair fields of Italy, in the vast strides that have been made in the science of overcoming obstacles to human progress, the blasting agent has played no minor part.

The last century has been a period of such wonderful achievement in every branch of human effort, and such marvelous things have been accomplished, that we may reasonably look forward to similar results in the next century.

Taking this view of the matter, some very extraordinary, and, I may say, chimerical, things have been suggested as coming possibilities.

Numerous are the novels that have been founded upon conceptions of inventions which would be absolutely impossible in this material world. We have heard of disintegrators — certain electrical machines which are to destroy armor-plate at a great distance with etheric vibrations. Such prophets have foretold electrical devices by which powder-magazines of battle-ships shall be exploded. We are told of torpedo-boats and other war vessels which will be manless, and controlled from the shore through enormous distance, enabling naval battles to be fought without human sacrifice. Some very terrible devices have been prophesied for land warfare, by which whole armies are to be smitten with an electric shock, and destroyed in an instant. Flying-machines have been promised, which will be capable of carrying ship-loads of passengers and freight, and, in war, even heavy guns.

While the future has in store some marvelous inventions and some great surprises which will exert a revolutionary influence in warfare on both land and sea, nothing supernatural is going to happen.

Furthermore, it must be borne in mind that, although we have witnessed the most extraordinary developments of the arts and sciences by inventive genius during the last hundred years, still there were certain things a hundred years ago which were well-nigh perfected, and which, therefore, have not been materially improved. The ax with which the woodman fells the tree is essentially the same ax that Hendrik Hudson gave to the Indians, the use of which they misunderstood, and which they hung about their necks as an ornament. The modern sword, the spear, and the cutlass, are no better than Damascus blades or those of Toledo.

The steam-engine is recognized to-day as having reached about the limit of its perfection, so that we are able now to make this pronouncement without fear of rational contradiction — that the genius of the next century will not and cannot advance steam engineering to a like extent.

Electricity is a new science, practically a child of very recent years, and by the close of the twentieth century it is possible that electrical engineering will have reached a similar approach to perfection to that now attained by steam engineering. The strange and the marvelous always have a charm for the human mind. Electricity is less understood by the multitude than are the simpler problems of mechanics. Electrical science is circumscribed, however, by the same inexorable natural laws as are all those things which we better understand, and it is just as impossible to accomplish impossibilities by means of electricity as with steam.

The improvements which are most probable in naval and military science will be along the lines of mobility. The ponderous armorclad will become obsolete within the next fifty years,— possibly within the next ten years,— and will be replaced by the swift cruiser with very light armor, or with no armor at all, and with small torpedo-boats capable of

traveling at an enormous speed. The warfare of the future, on both land and sea, will be largely one of high explosives. The question of placing high explosives to best advantage is a problem for the next decade.

It is probable that the most marvelous accomplishment in the field of electrical science, which will be utilized in future warfare, is an invention of the latter part of the nineteenth century. I refer to wireless telegraphy. The far-reaching utility and influence of this discovery — for it is a discovery as well as an invention — is destined to be very great, especially, as by future improvements, its range shall be increased and the invention simplified.

Invention offers a field of endeavor to young men, unequaled in opportunities and possibilities, and America, of all countries, is the most favorable to enterprise. For an invention one can secure a patent giving him a monopoly of the fruits of his genius. Although our patent laws are faulty, like all human institutions, still they are the pillars which support the edifice of American industrial achievement.

The best advice to a young man who would become an inventor is: First acquire all the knowledge you can of natural laws and the nature and use of common things, and above all, the laws which govern man in his social relations, that you may learn his needs, and how the changed conditions, produced by the introduction of one invention, pave the way for new wants requiring new inventions. Keep your eyes open and your wits always about you. One can acquire knowledge only in proportion to his ability to ask himself questions. If you would be a successful inventor, you must learn the magnitude of minor things and the littleness of even the greatest things. Whenever you see imperfection in the work of others, study that imperfection, and try to invent a better way. When you see a truly wonderful mechanism, do not take it for granted that it is perfect, but try to invent a way of simplifying it or of making it do its work still better. Never be deterred by the fact that others far superior to yourself in knowledge and experience may have spent a lifetime perfecting what you are attempting to improve. Remember that photography, as an example, owes its high state of perfection to the discoveries and inventions of amateurs more than to professionals. A boy eighteen years old invented the revolving turret, which was afterward utilized by Ericsson on the "Monitor."

All progress is born of inquiry. Doubt is often better than overconfidence, for it leads to inquiry, and inquiry leads to invention.

Remember, too, that great inventions are never dreamed out, they are always wrought out by wide-awake thought. Bryant said:—

"Deem not the framing of a deathless lay
The pastime of a drowsy summer day."

So with invention. It is always the reward of work. Great inventors are always great workers. No man can be a great inventor until the act of inquiry and invention becomes a passion and the passion becomes his master. No man is lazy at the job he loves, and no man invents anything when he does not love his job. The pleasure of making a new discovery, the pleasure of being the first to think of a better way of doing something is often the source of the keenest delight of which the human mind can be conscious.

When the stimulus of inquiry — the spirit of invention — is once introduced, then the hardest work is never drudgery, but drudgery becomes a pleasure, bringing profit and success.

Guns and Gunmaking. — Though the term "gun" is still applied to cannon and artillery, it more accurately embraces the variety of military small arms and sporting weapons. The improvements in military weapons from the era of the early arquĕbus, flint-lock, smooth-bore, muzzle-loading muskets down to that of the Enfield and Lee-Metford rifles, the Prussian needle-guns, the Mauser and the Krag-Jörgensen rifles, and the rapid-firing, breach-loading, and magazine guns, have been great. Greatly more effective have the latter also become by the use of the conical bullet, improved smokeless powder, and the spiral grooves wrought in the gun bores, which enable the ball to traverse the air with less resistance than the old spherical ball, to cover greater distance, and vastly increase its penetrating power. Rapid firing has been another gain in recent years, chiefly due to the invention of Hiram Maxim, by whose devise the modern rifle and the machine gun is operated automatically. A death-dealing instrument is that perfected by Dr. Gatling in his machine gun, with its several barrels of rifle caliber, which can fire 450 rounds a minute, or with the Accles gun-feed attachment, can now fire 1,200 rounds a minute. Very destructive also is the Maxim pom-pom, or 1-pounder automatic gun, and the same inventor's 9-pounder gun on much the same principle, which fire 60 rounds per minute. Like improvements have also been introduced, and with powerful effect, in heavy guns, such as those devised and constructed by Sir William Armstrong in England, General Rodman in the United States, and Herr Krupp in Germany. The use of improved powder and high explosives has also greatly increased the effectiveness and precision of these destructive weapons.

Cannon Ball, Largest Size Ever Fired. — The largest projectile ever fired from a cannon was 2,600 lb., from the largest gun yet manufactured. This gun was made at the works of Krupp, at Essen, for the Russian government, and has been placed in the fortifications of Cronstadt. Its caliber is 16¼ in., length of barrel 44 ft., is made

of the finest cast steel, and weighs 135 tons, or about 270,000 lb. It has a range of twelve miles, and can be discharged twice in a minute. The cost of each shot has been estimated at $1500. The heaviest English gun weighs 111 tons, and its shot 1,800 lb. The shot discharged by the second Woolwich Infant weighed 1,650 lb., the gun itself 80 tons, and for each discharge 300 lb. of gunpowder was required. The Italians fire shot of 2,000 lb., and the French of 1,984 lb. There are some ancient guns of very large dimensions in existence, but they do not carry heavy charges. Numbers were made in India, the largest being known by the name of "Malick è Meidan," or Lord of the Plain, which was 14 ft. long, had a 28 in. bore, and fired a ball 1,600 lb. in weight. "Mons Meg," at Edinburgh Castle, Scotland, is 13 ft. long, with a caliber of 20 in.

Cannon were first used in the 14th and 15th centuries, when they were cast in bronze at Nuremberg, Augsburg, and other towns in Bavaria and west Prussia. Compared with modern artillery for field purposes, they were then large, cumbrous, and heavy pieces of ordnance, wide-mouthed, and made, as we have said, either of bronze, or of iron bars, hooped together with iron rings. The projectiles were at that early period usually stones, afterward substituted by iron balls. For these early weapons of destruction there were various names, such as bombards, culverins, serpentines, etc., such as were made use of by Edward III. at Créçy and at Calais and by Louis XI. during his campaign in Flanders. At a later era came howitzers and mortars, with large bores, used for throwing bombs and shells into the air that they might fall into forts, besieged cities, or into an enemy's camp. Then came after the smoothbore rifled cannon, with spiral grooves cut into the surface of the bore to give the ball, as it leaves the muzzle of the gun, a twist to aid in the direction of its flight and increase its range, steadiness, and accuracy. The material of which cannon were made then changed, cast and wrought iron, brass and bronze, giving place in course of time to steel. With these improvements in material came improvements in design, form, size, and shape, such as the ordnance known as the Rodman gun, the Gatling machine (constructed with ten barrels, which revolved around an axis by a handle), and the formidable weapons familiar to-day as the Armstrong and the Krupp guns. The latter guns and other modern cannon weigh as much as 120,000 pounds, and will throw a destructive shot, with precision, a distance from 3,000 to nearly 9,000 yards, and penetrate (at a distance of 1,000 yards) a target of iron over two feet in thickness. Changes have also of late come over the form of the projectile, which, instead of being round, is now elongated, with a conical cast-iron point; while the charge of powder has increased greatly, especially in the case of

shell charged with nitro-gelatine or dynamite, and fired at long sea-range with annihilating effect. In the Boer war, the field weapons on both sides have been very destructive, being quick-firers, such as the Boer gun, of Schneider-Canet make. The British naval guns, mounted on field-carriages, have also been formidable weapons, such as Capt. Scott's 4.7 in. gun, which fires a shrapnel shell weighing 45 lb., with a velocity of 2,000 feet per second, and has an effective range of 12,000 yards or more. Another naval weapon which has been employed by the British army in the field is Scott's long 12-pounder, which differs considerable from the ordinary horse artillery 12-pounder, being about five feet longer and having a greater range.

INVENTIONS, SYNOPSIS OF GREAT.

INVENTION	INVENTOR	DATE
Air Gun	Marin	1595
Air Pump	Otto von Guericke	654
Anchor	Anacharsis	594 B.C.
Balloon	Montgolfier	1783
Barometer	Evangelista Torricelli	1643
Bellows	Anacharsis the Scythian	593 B.C.
Cannon	Chinese	About 618 B.C.
Clock	First one erected in Padua	11th century
Compass	Chinese	1115 B.C.
Cotton Gin	Eli Whitney	1793
Dial	Anaximander	550 B.C.
Electric Light	Sir Humphry Davy	1813
Engraving	Chinese	1000 B.C.
Fire Arms	Unknown	1364
Fire Engine	Hautsch	1657
Gas	Van Helmont	1600–1625
Gas Meter	Clegg	1815
Geographical Maps	Anaximander	550 B.C.
Glass	Phœnicians	....
Gunpowder	Berthold Schwarz	1320
Hydraulic Press	Joseph Bramah	1796
Lightning Conductor	Benjamin Franklin	1752
Locomotive	Watt	1759
Matches	Walker	1827
Organ	Archimedes and Ctesibius	220–100 B.C.
Phonograph	Thomas A. Edison	1877
Photography	Thomas Wedgwood	1802
Piano Forte	Bartolommeo Cristofali	1714
Printing	Johann Gutenberg	1438
Railroad	Beaumont	1672
Sewing Machine	Elias Howe	1841
Steamboat	Robert Fulton	1807
Steam Engine	James Watt	1763
Telegraph	Samuel F. B. Morse	1837
Torpedo	David Bushnell	1777
Telephone	Gray, Bell, Dolbear, Edison	1877
Telescope	Lippersheim and Adriansz.	1608
Thermometer	Drebbel	1609
Watch	Said to have been first invented at Nuremberg	1477

Inventions.—The man who invented the return ball, an ordinary wooden ball with a string attached to pull it back, made $1,000,000 from it.

Every one has seen the metal plates that are used to protect the heels and soles of rough shoes, but every one doesn't know that within ten years the man who hit upon the idea has made $250,000.

One of the cleverest inventions ever passed on by the Patent Office, is the machine for sticking common pins into the papers in which they are sold. The contrivance brings up the pins in rows, draws the paper into position, crimps it into two lines, then, at a single push, passes the pins through the paper and sets them into position. The machine almost seems to think as it works and to examine the paper to see if it is properly folded before pushing the pins into place.

The gimlet-pointed screw has produced more wealth than most silver mines, and the Connecticut man who first thought of putting copper tips on the toes of children's shoes is as well off as if he had inherited $1,000,000, for that's the amount his idea has realized for him.

Perpetual Motion, Nearest Approach Ever Made to It in Mechanics.—An inventor has patented a double electric battery which seems to come exceedingly near to perpetual motion. Instead of using the zinc battery, he professes to have hit upon a solution which makes a battery seven times as powerful as the zinc battery, with absolutely no waste of material. The power of the battery grows gradually less in a few hours of use, but returns to its original unit when allowed to rest a few hours. He has two batteries so arranged that the power is shifted from one to the other every three hours. A little machine has been running for some years in the Patent Office at New York. Certain parts of the mechanism are constructed of different expansive capacities, and the machine is worked by the expansion and contraction of these under the usual variations of temperature. In the Bodleian Library at Oxford there is an apparatus which has chimed two little bells continuously for forty years, by the energy of an apparently inexhaustible "dry-pile" of very low electrical energy. A church clock in Brussels is wound up by atmospheric expansion induced by the heat of the sun. As long as the sun shines this clock will go till its works wear out. Mr. D. L. Goff, a wealthy American, has in his hall an old-fashioned clock, which, so long as the house is occupied, never runs down. Whenever the front door is opened or closed, the winding arrangements of the clock, which are connected with the door by a rod with gearing attachments, are given a turn, so that the persons leaving and entering the house keep the clock constantly wound up.

SOUND

How Sounds Are Produced

If you look closely at a tuning fork, or a piano string, while it is sounding, you will see that it is swinging rapidly to and fro, or *vibrating*. If you touch it with your finger and stop its vibration, you will find that it no longer produces sound. The only difference that you can discover in the fork or string when sounding and when silent is that when it is silent it is without motion, and when producing sound it vibrates. From this it is natural for us to infer that the sounds produced are due to the vibrations of the sounding bodies. This inference has been confirmed by the examination of so many sounding bodies that it is now universally believed that all the sounds we hear are produced by vibrations.

The question that next presents itself is, how the vibrations of sounding bodies affect our ears, so as to produce the sensation of hearing. This may be made clear by a very simple, but striking, experiment. If a bell that is arranged to be rung by clock-work is suspended by a small cord under the receiver of an air pump, and the air then pumped out, the sound of the bell will grow faint as the quantity of air in the receiver decreases, and finally will cease altogether. By looking through the glass of the receiver, however, the bell may be seen ringing as vigorously as at first. Evidently the air around a sounding body plays an important part in the transmission of the vibrations to our ears. The way in which the air acts in transmitting the vibrations is as follows. At each vibration of the sounding body, it compresses, to a certain degree, a layer of air in front of it. This layer, however, does not remain compressed, for air is a very elastic substance, and the compressed air in front of the sounding body soon expands, and in doing so it compresses a layer of air just beyond it. This layer expands in its turn, and compresses another layer still further from the body. In this way waves of compression are sent through the air, at each vibration, in all directions from the vibrating body.

It must not be thought that particles of air travel all the way from the vibrating body to the ear when a sound is heard. Each particle of air travels a very short distance, never any further than the vibrating body moves in making a vibration, and the movement of the air particles is a vibratory one, like that of the sounding body. But the particles of air near the sounding body communicate their

vibrations to other particles, further from that body, and these, in turn, to others still further away, so, while the particles of air themselves move very short distances, the waves produced by their vibrations may be made to travel a considerable distance.

Ordinarily, the size of a sound wave is very small, but sound waves of such size and strength are sometimes produced, as to strike upon our ears with force sufficient to rupture our ear drums. Such waves are due to explosions, such as the discharges of large cannon or the explosions of large quantities of gunpowder or other explosives. The wave, produced by an accidental explosion in England, is said to have been so large, that it pressed inward the leaden sashes of the windows in a church three miles from the place where the explosion occurred.

What Is Sound?

From what has already been said, you will probably say that sounds are vibrations in the air, which produce the sensation of hearing. This is true, but we need not limit the definition of sound to vibrations of the air. Other elastic bodies can be set to vibrating in the same way, and their vibrations, when conveyed to our ears, produce the sensation of hearing. If you put your ear under water and then strike two stones together in the water you will hear a sound as readily as you would in air. Sound waves may be transmitted by solid bodies also, and some of these are better for this purpose than air or liquids. Perhaps you have tried the experiment of placing your ear against one of the steel rails on a railroad track to listen for the coming of a distant train. If you have tried this, you know that a sound that is too faint, or is made too far away, to be heard through the air, can easily be heard through the rail.

In view of the fact that other substances than air can be thrown into vibrations that will affect the sense of hearing, we may define sound as *vibrations in any elastic substance, that produce the sensation of hearing.*

This definition is sometimes called the *physical definition of sound*, in contradistinction to another, which is known as the *physiological definition.* The latter defines sound as the *sensation produced when vibrations in elastic substances are transmitted to our ears.* You will see at once that *sound* as defined in the physical definition is the *cause of sound* as defined in the physiological definition. When the term *sound* is used, without qualification, it may have either meaning, and for this reason statements about sound may be misleading, if it is not known in what sense the term is employed.

The Speed at Which Sound Travels

When sounds are produced near us, they reach our ears so quickly that it seems as though no time were taken for their transmission; but if you have ever seen a gun fired by a person at some distance, you must have noticed, that after the flash is seen, a perceptible time elapses before you hear the sound. It takes some time for the light from the flash to reach your eyes, but that time is so very short, that you cannot appreciate it. The sound travels much more slowly, however, and the time taken by it in traveling a few hundred yards is noticeable. Many measurements of the speed of sound transmission have been made, and it has been found that sound usually travels in air at a rate of about eleven hundred feet a second. This rate is not always the same, however, for there are a number of circumstances that cause it to vary. When the air is heated, it expands and becomes lighter, and the speed with which sound travels in it is increased. At the freezing point, sound travels through the air at the rate of 1,091 feet a second, and for every increase in temperature of one degree, on a common Fahrenheit thermometer, the speed is increased by about thirteen inches a second. Accordingly at 68° F. the speed would be about 1,130 feet a second. Moisture in the air also makes it lighter, and consequently sounds travel faster in moist air than in dry.

In other gases the speed of sound transmission may be greater or less than in air. For example, in hydrogen gas, which is much lighter than air, sound travels nearly four times as fast as it does in air. On the other hand, in carbonic acid gas, which is heavier than air, sound is transmitted more slowly.

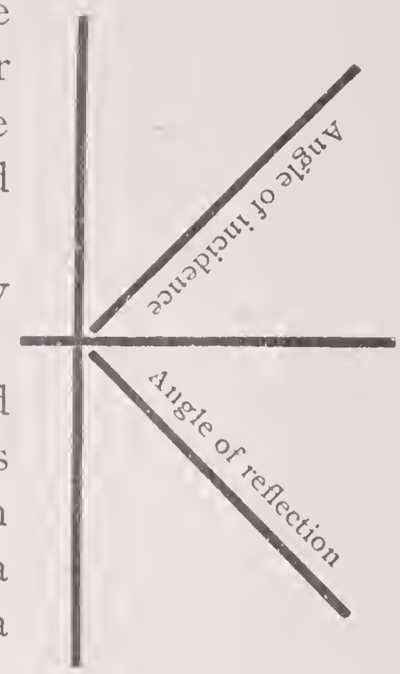
In liquids, which are always heavier than air, you might expect sound to travel more slowly than it does in air, but this is not the case. Liquids are less compressible than gases, and their greater incompressibility more than compensates for their greater weight, thus causing the speed with which sound is transmitted in them to be increased. In water, for example, sound travels about four times as fast as in air.

Most solids are even better mediums than liquids for the transmission of sound. In iron and glass, which are both incompressible, sound is transmitted sixteen times as fast as in air.

Reflection of Sounds — Echoes

When sound waves are produced in air they travel in all directions from their starting point, until they become so small and weak that

they can no longer affect our ears. If, however, they strike against a wall, or the face of a cliff, they are stopped and *reflected*, or turned back, thus giving rise to echoes. No doubt you have observed that if you stand some distance from a building, facing one side of it, and shout, the sound of your voice will soon strike your ears again, but with less force than when you shouted. The second sensation is produced by the reflection of the sound wave from the side of the building.



If you stand some distance from a wall, but not directly facing it, and shout, the sound is reflected as before, but it does not return to your ears. Instead, the reflected sound wave travels away from the wall, along the line that makes the same angle with it as that made by the line along which the sound traveled to the wall. So, a person standing in a position corresponding to yours, but on the other side of a line drawn perpendicular to the wall, would hear the echo.

This action of sound waves is sometimes described by the statement that *the angle of incidence equals the angle of reflection.* The angle of incidence is the one made with the wall by the incident, or striking wave, and the angle of reflection is that made by the reflected wave.

The echoes produced in mountainous regions, where there are many cliffs of smooth rock to reflect the sound, are sometimes startling. The report of a rifle will echo and reëcho among the rocks so many times that it sounds as if several rifles had been fired. In large buildings, also, the echoes are sometimes very remarkable, a word undergoing several reflections and finally coming back to the hearer from the most unexpected places. There is a hall in the Capitol at Washington, in which the echoes are so peculiar, that the guides always demonstrate them to visitors.

Another very interesting phenomenon, which is dependent upon the reflection of sound, is seen in whispering galleries. These are hallways that have curved ends and are so constructed that when a person stands at a certain point near one end of the hall and speaks in whispers, he may be heard by a person standing at a similar point near the other end, but not by persons standing midway between the two points. This phenomenon may be explained by means of the diagram shown in Fig. 1.

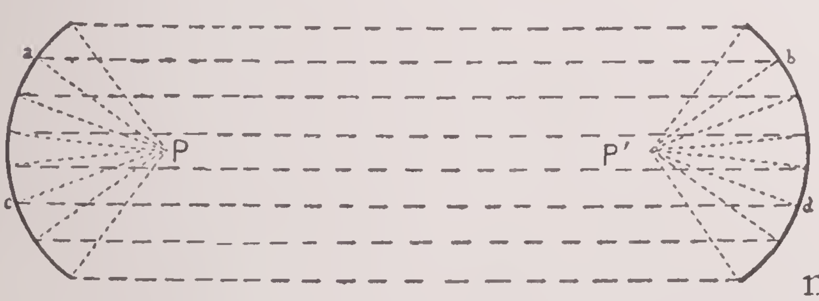


Fig. 1

If a person stands at the point P and speaks, the waves striking the end of the gallery are reflected along the lines a b c d, etc., and

striking the opposite end of the gallery, are reflected to the point P′. When the waves are brought together again at P′ they are almost as strong as at P, but at points between P and P′ they are so weak as to be inaudible.

Properties of Sounds

Sounds are distinguished from each other by the degree to which they possess three qualities, namely: loudness, or intensity; pitch; and quality, or timbre.

The intensity of any sound that we hear depends upon the size, or *amplitude*, of the waves that enter our ears. The amplitude of a sound wave gradually decreases, as the wave travels from its starting point, consequently the loudness of a sound depends upon the distance of the hearer from the point at which the sound was produced. You know from experience that this is true, and if you think of the matter for a moment you will see why it is so. When a wave starts from a sounding body it affects only a small quantity of air, but for every inch it travels the quantity of air to which the vibration is transmitted becomes larger, and the amplitude of the vibrations must grow correspondingly smaller, just as when a pebble is dropped into water, the ripples produced by it are highest at the point where the pebble struck the water, and grow lower and lower as their circle widens.

It has been found possible to measure the amplitude of a sound wave, at different distances from the point from which it started, and from these measurements it has been learned that the decrease in the amplitude of the wave, in the open air, follows a fixed rule that is stated thus: *The amplitude of a sound wave at any point is inversely proportional to the square of its distance from its starting point.* This rule is called "the law of inverse squares," and it means that if the amplitude of a wave be measured at two points, distant one hundred, and two hundred, yards, respectively, from the starting point of the wave, the amplitude of the wave at the former point will be found to be four times as great as at the latter.

You have seen that the decrease in amplitude of a sound wave as it travels through the air, is due to the fact that the quantity of air set in motion by it is constantly increasing. Now, if a wave is transmitted through a tube containing air, the quantity of air to which the vibrations are communicated does not increase as the wave travels forward, and theoretically there is no decrease in amplitude. When a wave is actually transmitted in this way, however, it is found that there is some decrease in amplitude, on account of the friction of the particles of air against the sides of the tube; but the decrease from

this cause is much slower than that which occurs in the open air, and consequently sounds can be heard at much greater distances through tubes than through the open air. Tubes for speaking purposes are frequently used to connect different parts of the same building, and if the tubes are not too crooked they serve their purpose very well.

Pitch is that property of sounds that enables us to distinguish them as *high* or *low*. The pitch of a sound is determined by the number of vibrations a second, made by the body that produces it. The sound of an explosion has no pitch because it produces only one wave in the air. Neither has the sound of a wagon jolting over a stone pavement any definite pitch, for it is a mixture of sounds, in which the numbers of vibrations a second are not the same. Pitch is a property of continuous sounds only, and it is apparent chiefly in musical sounds, by which we mean sounds that produce pleasant sensations. In music, however, pitch is of extreme importance. In a musical instrument, the parts are so arranged that the sounds produced can be given any desired pitch, and it is by controlling the pitch of the sounds that the pleasing effect of music is in large measure produced. Sounds of low pitch are produced by bodies making few vibrations a second, and the sounds are said to be of *low vibration frequency*. High-pitched sounds are produced by bodies that vibrate rapidly, and they have *high vibration frequencies*.

Quality, or *timbre*, may be defined as that property of sounds which enables us to distinguish the notes produced by different instruments. Two notes, one of which is produced upon a piano, and the other upon a violin, may have the same pitch and be equally loud, yet they are easily distinguishable. The difference in them is due to the presence of what are called *overtones*, of which more will be said later.

The Length of Sound Waves

By the length of a sound wave, we mean the distance from the point of greatest compression in one wave to the point of greatest compression in the next. This depends upon the pitch of the sound produced, for if a sounding body is making one hundred vibrations a second, by the time the one hundredth vibration is made, the wave from the first vibration will have traveled about eleven hundred feet from the starting point, and the remaining ninety-eight waves will lie between the first and the one hundredth. In consequence of this fact, the wave length for that particular sound will be about eleven feet. If the sounding body had made eleven hundred vibrations a second by

the time the first wave had traveled eleven hundred feet, there would have been eleven hundred waves produced, and the wave length for that sound would be one foot. The wave lengths of sounds produced by the human voice usually vary between one and eight feet, though some singers have produced notes having wave lengths as great as eighteen feet, and others have reached notes so high that the wave length was only about nine inches.

Reinforcement of Sound Waves

When a tuning fork is struck, it produces a sound so faint that it can scarcely be heard unless the fork is held near the ear; but if the end of the fork is held on a box or table, the sound rings out loudly and seems to come from the table. The explanation of this is very simple. When only the fork vibrates, it produces very small sound waves, because its prongs are small and cut through the air. But when it is set on a box or table, its vibrations are communicated to the support, and the broader surface of the box or table sets a larger mass of air in vibration, and so intensifies the sound of the fork. When a surface is used in this way to reinforce the vibrations of a small body, and thus produce sound waves of greater volume, it is called a *sounding board*. Many musical instruments, like the violin and the piano, owe the intensity of their sounds to sounding boards, which reinforce the vibrations of their strings.

Columns of air, like sounding boards, serve to reinforce sound waves. Unlike sounding boards, however, they do not respond equally well to a large number of different sounds. They respond to one sound only, or to several widely different ones. This may be shown as follows: Take a glass tube about sixteen inches long, and two inches in diameter, and after thrusting one end of it into a vessel of water, hold a vibrating tuning fork over the other end. By gradually lowering the tube into the water a point will be reached at which the sound becomes very loud, and as this point is passed the sound gradually dies away. By raising the tube the sound is again made loud when the tube reaches a certain point. This shows that to reinforce sound waves of a certain vibration frequency, the column of air in the tube must be of a certain length.

Let us now see why the waves produced by the tuning fork are reinforced only by a column of air of a certain length. When the prongs of the fork make a vibration, a wave of air is produced which enters the tube, goes down to the water, is reflected, and comes back toward the fork. Now, if the reflected wave reaches the fork at the

precise moment when it has completed one-half of its vibration and is about to begin upon the second half, it will strengthen the wave produced by the second half of the vibration; but if the reflected wave reaches the fork before or after the beginning of the second half of the vibration, it will not reinforce it. The action of the air in the tube will be more readily understood from the accompanying diagram. (Fig. 2.) At the downward movement of the lower prong of the tuning fork, a wave of compression is sent down the tube, and is reflected at the surface of the water. In order to reinforce the wave produced by the prong when it moves upward, the reflected wave must reach the fork just at the time that the prong reaches its normal position (shown by the heavy line), and before it starts upon the second half of its vibration.

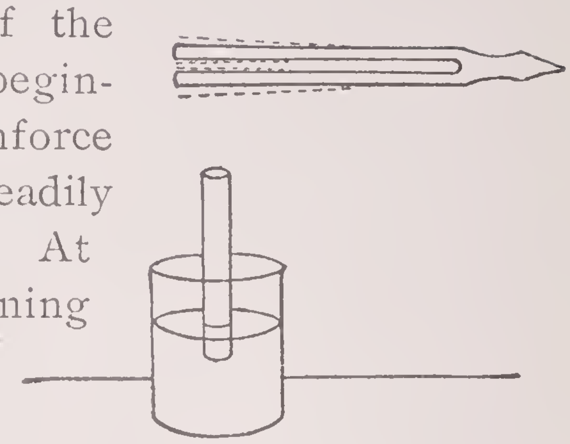


Fig. 2

Not only do columns of air tend to reinforce notes having a certain rate of vibration, but all elastic bodies have a certain rate at which they tend to vibrate, and when sounds having the same rate of vibration are produced near them, these bodies will vibrate in sympathy with them. If the sounds be kept up long enough, the sympathetic vibrations in objects near them sometimes become so great that they can easily be seen. Goblets and tumblers made of thin glass show this property very strikingly. When the proper notes are sounded the glasses take up the vibrations, and give a sound of the same pitch. If the note is loud, and is continued for some time, the vibrations of a glass sometimes become so great that the glass breaks. Large buildings, and bridges also, have rates at which they tend to vibrate, and this fact is the foundation for the old saying, that a man may fiddle a bridge down, if he fiddles long enough.

Musical Instruments

By *musical sounds* are meant sounds that are pleasant to hear, and their combination in such a way that their effect is agreeable produces *music*. Any instrument, therefere, that is capable of producing pleasing sounds may be called a musical instrument, and music is sometimes produced by very odd devices; but by musical instruments we ordinarily mean instruments that are especially designed to produce musical sounds. The number of such instruments that have been invented is enormous, but all of them may be divided into comparatively few classes, only two of which are of much importance. The two classes referred to are stringed instruments and wind instruments.

Stringed musical instruments are those in which the sounds are produced by the vibrations of a number of strings, and are generally

reinforced by a sounding board. The strings are arranged in the instruments in such a way that the pitch of the sound produced by each string shall bear a certain relation to the pitch of those obtained from the other strings. As long as this relation exists, the instrument is said to be *in tune*, and when the relation is destroyed, the instrument is *out of tune*, and the music produced by it is apt to contain what we call *discords*.

The conditions that determine the pitch of sounds produced by strings can be very easily discovered by experiment. Thus, by taking two pieces of the same wire, one twice as long as the other, and stretching them equally, you will observe on striking them that the shorter one yields the higher note. If their vibration frequencies are measured it will be found that the shorter string has a vibration frequency just twice as great as that of the longer string. From this we conclude that when two strings of the same size (and material) are stretched equally taut, their vibration frequencies are inversely proportioned to their lengths.

By now taking two pieces of wire, of the same size and length, and stretching them so that the tension of one is four times as great as that of the other, we shall find that the vibration frequency of the tighter string is just twice as great as that of the looser. Thus, we see that the vibration frequency depends upon the tension applied to a string, and, that in strings of the same size and length, the vibration frequencies are proportional to the square roots of their tensions.

Now taking two strings of the same length, but with the diameter of one twice as great as that of the other, and stretching them equally, we shall find that the vibration frequency of the smaller string is twice that of the larger; which shows that when the lengths and tensions of two strings are equal, their vibration frequencies are inversely proportional to their diameters.

In constructing stringed instruments, advantage is taken of each of these conditions that affect the vibration of strings and the requisite pitch is secured in a string by choosing one of convenient length and diameter, and by stretching it to just the right tension.

When a string is plucked in the middle, it vibrates as a whole, and its rate of vibration, or *vibration frequency*, is determined by the three conditions that have just been discussed; but if a finger is laid on the string, in the middle, and the string is plucked between the middle and the end, the string will vibrate in halves, and the middle point will remain at rest. If the string had been touched at a point one-fourth of the length from the end, it would have vibrated in fourths, and there would have been three stationary points. When a string vibrates in parts, in this way, the rate of vibration is the same

as that of a string of the same length as one of the vibrating parts, or segments, and having the same diameter and tension. The stationary points in a string that is vibrating in segments, are known as *nodes;* and points where the amplitude of the vibration is greatest are called *antinodes*.

When vibrations are set up in a string, with nothing to prevent the free vibration of the whole string, it first vibrates as a whole, and the sound produced is known as the *fundamental tone* of the string; but very soon smaller vibrations of segments of the string begin, first of halves of the string, then of thirds, and then of fourths, as shown in B, C, D, and E. (Fig. 3.) These smaller vibrations produce sound waves that blend with the fundamental tone and are known as *overtones*. The combined sound of the fundamental tone and the overtones is called a *note*. The overtones present in notes that have the same fundamental tone are not the same when the notes are produced by different instruments, and, consequently, the sound of notes of the same pitch is not the same on different instruments. This difference in notes of the same pitch has already been mentioned, but the way in which overtones are produced was not explained in connection with it.

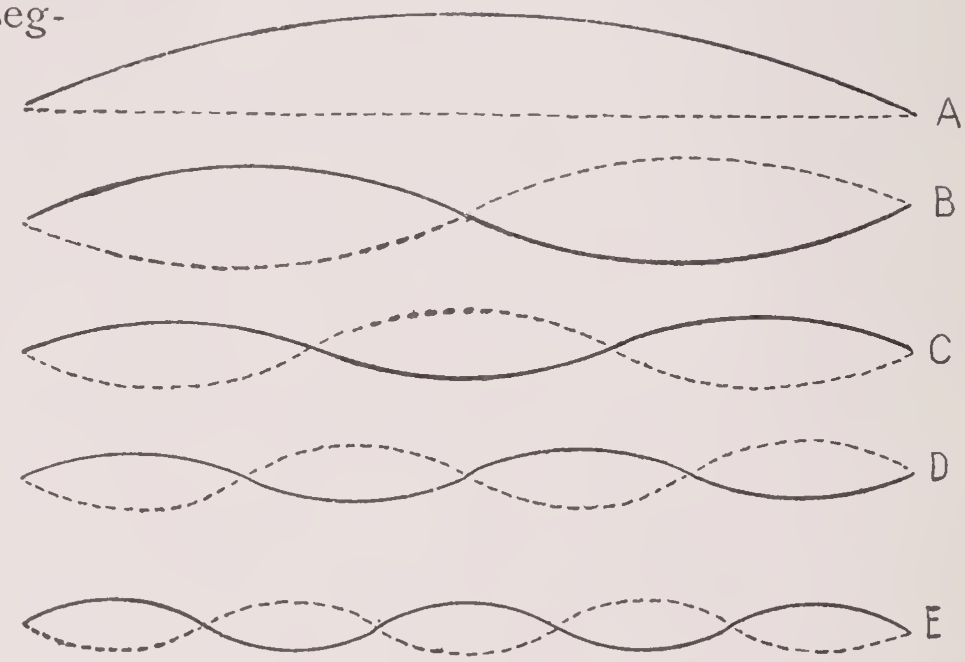


Fig. 3

In wind instruments the sounds are produced by the vibrations of columns of air in pipes. In the organ, which is probably the best example of a wind instrument, the vibrations are usually produced by causing a current of air to strike a sharp edge, just above the opening of the pipe, as is done in a common whistle. A portion of the air current is deflected into the organ pipe, and it sets up vibrations in the air within the pipe.

The pitch of the sound produced by an organ pipe is determined by the length of the pipe. A pipe that is open at both ends, called an open pipe, produces a sound that has a wave length twice as great as the length of the pipe; and if the pipe is open at one end only, a closed pipe, the sound produced has a wave length twice the length of the open pipe. Hence it will be seen that a closed pipe produces a sound that has the same pitch as that produced by an open pipe that is twice as long.

In a closed pipe the air column forms a node, or point of no vibration, at the closed end of the pipe, and an antinode, or point where

the vibration is at a maximum, is formed at the open end of the pipe (see A and C, Fig. 4). In the open pipe, there can never be a node at either end, because both ends are open and vibration is at a maximum at each end (see A, B, and C, Fig. 4). This causes a node to form at the middle of the open pipe, that is, an open pipe is the equivalent of two closed pipes of half the length of the open pipe, placed with their closed ends together (see A and A′, Fig. 4).

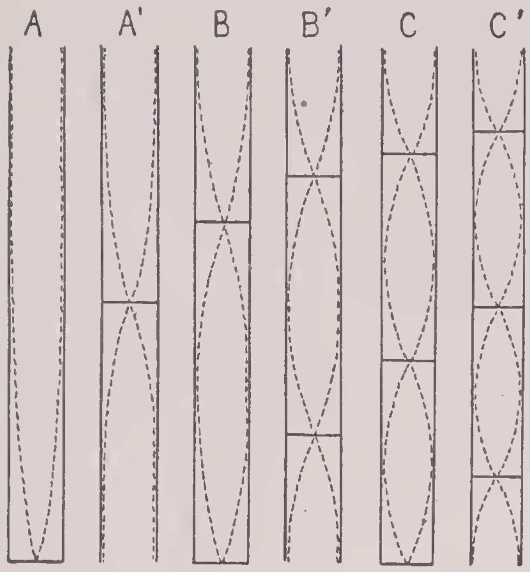


Fig. 4

It is easy to show that a node is formed at the middle of an open pipe, by lowering into it, while it is sounding, a small piece of very thin tissue paper, covered with sand. As the sand is lowered, it rattles violently against the paper, because of the vibration of the air, until it reaches the middle of the pipe. At this point, the absence of vibration in the air of the pipe is shown by the sand remaining quiet on the paper, but as soon as the middle is passed, the sand begins to rattle again, showing that the air is in a state of vibration beyond that point.

Along with the fundamental tone produced by the vibration of the air in an organ pipe, in the ways already described, there are present a number of overtones that are due to the vibration of the air in smaller segments. In the open pipes these overtones have vibration frequencies 2, 3, 4, 5, etc., times as great as the fundamental tone of the pipe, but in the closed pipe the overtones have vibration frequencies 3, 5, 7, etc., times that of the fundamental tone.

Talking Machines

The phonograph, graphophone, gramophone, sonophone, and other talking machines, furnish one of the best proofs of the wave theory of sound, because their invention was based upon that theory. The first talking machine was that invented by Thomas A. Edison and called by him the phonograph. The others merely show the principle of the phonograph applied in different ways, and need not be separately described. The reasoning that led Edison to invent the phonograph was that if the sound waves produced by the human voice were allowed to strike a thin disk of hard rubber or metal, they would cause the disk to vibrate in a certain way, and if the disk were again made to vibrate as it had done under the influence of the voice, the sounds of the voice would be reproduced. The difficult part of the task of making a talking machine was in finding a way to make the disk vibrate again as it did under the influence of the voice. This, however, was

finally accomplished, as shown in Fig. 5, by providing the disk with a needle, N, that rests on a cylinder of hard wax, C, which turns slowly under the point of the needle while the sound waves are striking the disk. The vibrations of the disk cause the point to indent the surface of the wax so as to produce a groove of varying depth on its surface. After the vibrations of the speaker's voice have been recorded in this way on the surface of the wax cylinder the needle can be made to retrace its path, and will cause the disk to vibrate as it did under the tones of the speaker's voice. These last vibrations of the disk produce sound waves similar to those of the voice, but their amplitude is less and the sound is not so loud.

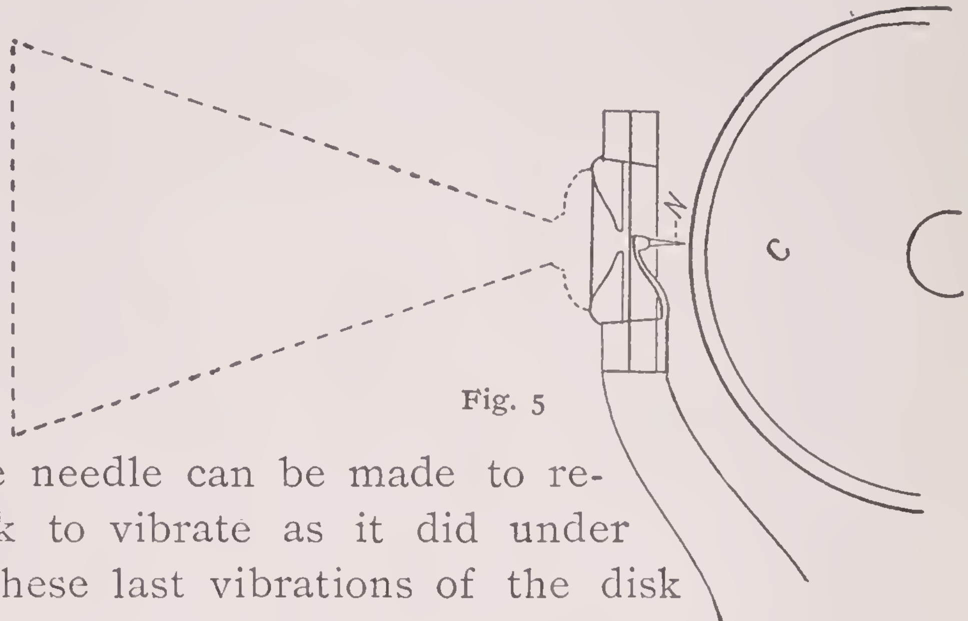


Fig. 5

Organ, Largest in the World

The largest organ in the world is at the Town Hall of Sydney, New South Wales, which took three years to build, and cost £15,000. The next largest is in Seville Cathedral, followed by one built at the expense of Mrs. A. T. Stewart, as a memorial to her husband, in the Cathedral of the Incarnation at Garden City, N. Y. It is divided into four distinct parts in widely separated localities of the cathedral — but under the control of one organist, and is worked by electricity.

Volume of Sound, How It Is Measured

Sound arises from vibrations giving a wave-like motion to the surrounding atmosphere, the wave gradually enlarging as it leaves the source of disturbance, while at the same time the motion of the air particles becomes less and less. The simplest method of determining the number of vibrations of a sound is by means of Savart's apparatus. This consists of two wheels — a toothed or cog-wheel and a driving-wheel. They are so adjusted that the cog-wheel is made to revolve with great rapidity, its teeth hitting upon a card fixed near it. The number of revolutions is indicated by a counter attached to the axis of the cog-wheel. Suppose that sound is traveling in the air at the rate of 1,000 ft. per second, and that Savart's wheel is giving a sound produced by 200 taps on the card per second, it follows that in 1,000 ft. there will be 200 waves or vibrations, and if there be 200 waves in 1,000 ft. each wave or vibration must be 5 ft. in length. The velocity of sound through air varies with the temperature of the latter, but is usually reckoned at 1,130 ft. per second.

TRANSPORTATION

It is almost impossible to conceive the progress made during the nineteenth century in the transportation of passengers and goods. The stage-coach without springs traveled the rough roads between cities and towns; and the sedan chair carried by men was used in the towns at the beginning of the century. The common people rode in a carrier's cart, or walked; the man rode astride on horseback while the woman sat behind him on a pillion, with her arms clasping his waist. The first springs for carriages were patented by Obadiah Elliot in 1804. The omnibus appeared first in London streets in 1829 and Victorias in 1869. The buggy is an American invention of the early part of the century and was considered a marvel of lightness and strength.

It is said that the first locomotive was invented by Oliver Evans of Philadelphia in 1787 and that a model of his invention was sent to England. Richard Trevithick made trial of his locomotive at Cambourne, England, on Dec. 24, 1801. His was the first to carry passengers by steam. It is amusing to read of the amazement and wonder which was evoked by this little, imperfect machine that traveled at the marvelous speed of five miles an hour and drew a load of ten tons. George Stephenson's first locomotive was made in 1814. The first railway in the world was opened on Sept. 27, 1825. It was the Stockton and Darlington road near Manchester, England. It was 38 miles long and cost a quarter of a million sterling. On this occasion the train consisted of 33 wagons with 450 passengers, weighing in all 90 tons. The last 8¾ miles were done in 65 minutes. On the return trip, without the loaded wagons of coal, the 12 miles were done in three hours and seven minutes. In 1829 the steam blast addition to the furnace enabled the «Rocket» to travel ten miles an hour. The opening of the Manchester and Liverpool Railway in 1830 almost excited a riot. The opposition to and the adverse criticism of the practicability of this mode of travel seems almost incredible.

The first railroad on the continent of Europe was established in Belgium in 1837 between Brussels and Mechlin. Railroads came into use generally in France in 1839. In America the Baltimore and Ohio road was opened in 1830 between Baltimore and Ellicot's Mills, a distance of 15 miles. In five years from that time there were over 1,000 miles of road in the United States. The «Stourbridge Lion» was the first locomotive used in America. It was on a coal road in Pennsylvania prior to 1830. The «York» won a prize of $4,000 offered in 1831 by the B. & O. for the most approved locomotive. The

"John Bull" made by the Stephenson's and brought to America in 1831 was exhibited at the World's Fair in Chicago in 1893. Peter Cooper's locomotive was built in 1831. In 1904 there are over 200,000 miles of road in the United States. These give employment to over a million of men and represent a capital of over $12,000,000,000. They carry over 600,000,000 passengers a year and 1,100,000,000 tons of freight.

Locomotive

The largest locomotive ever constructed prior to 1880 was that made at the Baldwin Locomotive Works during the early part of 1879. It was turned out ready for use April 10 of that year and named "Uncle Dick." "Uncle Dick" weighed 130,000 pounds, was 60 feet from headlight to the rear end of the tender. He is now at work on the Atchison, Topeka, and Santa Fé road. During the year 1883 the same works that constructed "Uncle Dick" turned out several locomotives for the Northern Pacific Railroad, each weighing 180,000 pounds. During the same year, as if to overshadow the Baldwin works, the Central Pacific Company caused to be built at their shops in Sacramento, Cal., what are really the largest locomotives in the world. They have 8 drive-wheels each, the cylinders are 19 inches in diameter, and the stroke three feet. These engines weigh, with the tender, as "Uncle Dick's" weight was given, almost 190,000 pounds. The Baldwin works, in 1899, completed for the Northern Pacific an engine weighing, with tender, 225,000 pounds.

Railways

The dates of the openings of the first railways, and the mileage in 1901 of the principal countries are:—

	MILES
Austria-Hungary — 20th September, 1828	16,467
Belgium — 5th May, 1835	3,215
Denmark — 18th September, 1844	1,223
France — 1st October, 1828	22,586
Germany — 7th December, 1835	25,969
Great Brit. and Ireland — 27th Sept., 1825	20,073
Greece — 18th February, 1869	239
Italy — 3d October, 1839	8,117
Netherlands — 13th September, 1839	1,887
Norway — 14th July, 1853	970
Portugal — 9th July, 1854	1,280
Russia — 4th April, 1838	19,027
Spain — 30th October, 1848	6,127
Sweden — 9th February, 1851	1,623
Switzerland — 15th June, 1844	1,929
Turkey — 4th October, 1860	1,096
Egypt — 26th January, 1856	1,494
India — 18th April, 1853	16,996
United States — 17th April, 1827	167,000
Canada — 19th March, 1847	14,000
Mexico — 18th October, 1850	5,827
Argentine Republic — 14th December, 1864	5,798
Brazil — 30th April, 1854	5,779
Chile — January, 1852	1,926
Colombia — January, 1880	230
Paraguay — 1st October, 1863	149
Peru — 29th May, 1851	994
Uruguay — 1st January, 1869	537
Venezuela — 9th February, 1866	441

Railroads, Total Mileage of, in the Chief Countries of the World

	MILES
United States (1899)	190,833
Germany (1898)	30.950
France (1889)	23,576
Russia (1900)	34,485
Great Britain (1899)	21,700
British India (1900)	23,763
Canada (1899)	17,358
Australasia (1899)	15,285
Austria-Hungary (1899)	20,908
Italy (1898)	9.747
Spain (1899)	8,068
Sweden and Norway (1899)	7,553
Holland (1898)	1,272
Switzerland (1899)	2,347
Denmark (1900)	1,711
Portugal (1898)	1,464
Japan (1898)	3,481

Street cars drawn by horses were first tried in New York in 1831 by John Stephenson. The track was of flat iron bands laid on stone. The car was like a large omnibus with thirty seats inside and thirty on the roof. It ran along the Bowery and Fourth Avenue from Prince Street to Harlem River. Horse-cars were installed in Boston in 1856 and in Philadelphia in 1857. Paris had them in 1858 and London in 1870. Cable-cars were introduced in 1873, the first being used in San Francisco. Chicago introduced them in 1881 and Philadelphia in 1883. They were used in New York in 1886 and in Baltimore in 1893. The trolley-car was first thought out by Thomas Davenport of Brandon, Vermont, in 1835. An electric locomotive that traveled 19 miles an hour, was tested on the Baltimore and Washington road in 1851. The first that proved really successful was made by Siemiens and Halaske of Germany in 1881. In 1903 an electric car ran for a short distance at a speed of over 125 miles an hour in Germany.

The fore-runner of the modern bicycle was the hobby-horse which was in use in England in the 18th century. It consisted of two wheels joined by a frame upon which was a saddle. The rider propelled the machine by taking steps upon the ground. The first velocipede was invented in Paris by Baron Von Drais in 1816; improved in England in 1818; and introduced into America in 1819. Dalzell a Scotchman, made an improvement in the form of a wooden bicycle. M. Michaux, in 1869, patented at Paris a form with the front wheel much larger than the rear wheel. A later form and one very popular in America had wheels of nearly equal size and propelled by pedals attached directly to the front wheel. Rubber tires, brakes, and other expedients made the motion more comfortable. The "ordinary" with a front wheel many times larger than the rear was in great favor for some years but was completely supplanted by the "safety" which appeared in 1883.

The automobile or motor-cycle was first thought of by a French army officer in 1769. He arranged a large copper boiler upon a gun-carriage. A resident of Cornwall, England, made a road-engine in 1784, and William Wymington in 1786 advanced another design. A

peculiar form of road-engine called the Orleton Amphibolus was seen in Philadelphia in 1804. In late years France has led in the manufacture of automobiles, because the roads are the property of the Government and are well kept up. The designs and methods by propulsion are many and varied. The principle has been applied to the motor-cycle. Automobile races are very popular in many countries as are also automobile exhibitions. The propulsion is by means of electricity, gasoline, or steam. In the many trials made in 1903 the gasoline took the greatest honors. The races of speed and endurance which have been made to decide the best make have often resulted in fatal accidents. On November 22, 1903, Barney Oldfield made the mile in 54⅘ seconds. Henri Fournier on the Coney Island Boulevard, New York, in November, 1901, made the American straightaway record of a mile in 51⅘ seconds. Probably the finest track in America is that on Florida Beach near Ormond and Daytona where a hard level track of twenty miles may be enjoyed. In the races between Paris and Madrid in 1903 Gabriel rode a Morse machine at an average speed of 66 miles per hour in Ireland. Jenatzy won the Gordon-Bennett race with a Mercedes. The Columbia made the record run from Chicago to New York in 76 hours. The Clement motor-cycle was driven a mile in 55⅖ seconds by Albert Champion in September, 1903.

The story of the development of the steam-boat is best told in the life of Robert Fulton.

"Great Eastern," The.—The largest ship ever built, the "Great Eastern," recently broken to pieces and sold to junk dealers, was designed and constructed by Scott Russell at Millwall on the Thames. Work on the giant vessel was commenced in May, 1854. She was successfully launched January 13, 1858. The launching alone occupied the time from November 3, 1857, until the date above given. Her total length was 692 feet; breadth, 83 feet; total weight when launched, 12,000 tons. Her first trip of any consequence was made to New York in 1859–60.

Aerial navigation has engaged the attention of students during recent years. The Montgolfier brothers in 1783 used a fire balloon, and ascents to a height of five miles have been quite frequently made. Giffard in 1852 first attempted to direct the course of a balloon. M. Santos-Dumont of France made great progress in 1902 in the discovery of a dirigible balloon. He was able in calm weather to encircle the Eiffel Tower of Paris, to alight at his own door and to resume his journey again. Professor Samuel P. Langley of Washington, D. C., made elaborate experiments with an aeroplane, under the direction of the War Department. His progress was encouraging although the machine is not yet perfected. Dr. Alexander Graham Bell made a very important series of experiments with kites of various shapes and sizes. From

these he has made valuable deductions in the theory of the science. Much attention has been directed to the study by the services of airship races to be held in 1904, at the Louisiana Purchase Exposition.

Canals are artificial water courses used for the purposes of navigation, for drainage and irrigation, and for the supplying of cities and towns with water. Canals for inland navigation have been in use in foreign countries for many centuries. The Grand Canal of China, over 600 miles in length, was built in the 8th century; while they are extensively used in most of the countries of Europe on level plains, even in competition with railroads. In this country canals date from the close of the 18th century, the first to be constructed being that around the falls of the Connecticut River at South Hadley, Mass. The Erie Canal, which traverses New York State from Albany to Buffalo, a distance of 350 miles, was built by the state and opened in 1825. Since then it has been both deepened and widened. Other early constructed native canals are the Chesapeake and Delaware, and the Delaware and Raritan, which connect the cities of New York, Philadelphia, and Baltimore. The Welland and the St. Lawrence canals, in the neighboring Canadian dominion, are examples of the utility of these inland boat and barge routes for the purposes of commerce, and to overcome natural obstacles such as waterfalls and rapids. To overcome the change of level in canalways the boats are generally raised by means of locks and sometimes by lifts and cars. Other American canals of note are the St. Mary's, Mich., which unites Lake Superior with the other Great Lakes; the Illinois and Mississippi Canal, 77 miles in length, from Hennepin to Rock Island, Ill.; the Illinois and Michigan; and the Dismal Swamp Canal (22 miles long) which connects Chesapeake Bay with Albemarle Sound, and affords access to about 2,500 miles of river and bayou navigation in the Carolinas.

Another important canal enterprise in the New World is known as the Chicago Drainage Canal, connecting the Chicago River with the Illinois River by way of the Desplaines River. In this undertaking the current in the Chicago River is turned backward and made to discharge its waters into the Mississippi, instead of by way of Lake Michigan into the St. Lawrence. The object of this was to get rid of the sewage of Chicago without contaminating the clear, pure water from Lake Michigan, which is now obtained for city and sanitary purposes at the rate of 300,000 cubic feet per minute. The cost, so far, of the work has been over $33,000,000. Other canal enterprises in this country, in the way either of new construction, or of deepening, widening, and otherwise improving existing artificial waterways, are projected.

The important project is anew broached to construct a ship canal to shorten the route between the Atlantic and the Pacific oceans by a

waterway across Central America. French capitalists began some years ago to construct an Isthmian sea-level canal at Panama; but the work performed was a mere fraction of the whole, and out of all proportion to the expenditure, and the project collapsed. The consensus of American opinion has favored, however, the Nicaragua route, utilizing Lake Nicaragua as a summit-level, and the more practicable means of constructing an Isthmian canal. The report of a commission on the subject has recently been submitted to Congress, and the enterprise is likely, ere long, to be undertaken. Its dimensions are to be a depth of 35 feet at mean low water, a bottom width of 150 feet, with a double system of locks throughout (save in Lake Nicaragua) 740 feet by 84 in length and breadth, and 35 feet in depth. The canal will be about 170 miles in length (less 56 miles through Lake Nicaragua). The route designed to be followed is from Greytown (San Juan del Norte), *via*, in part, San Juan River to Fort San Carlos, and after traversing Lake Nicaragua, will proceed from La Virgen by the Rio Lajas to Brito on the Pacific. It is estimated that the enterprise will take ten years and an expenditure of 200 million dollars to construct. More recently, the United States has been offered by the French proprietors their rights in the abandoned Panama Canal at a cost of $40,000,000. This proposal, as we write, is now under consideration by Congress, as well as the alternative proposal of the Nicaragua Canal scheme.

In the Old World the most useful ship canal, as well as profitable, is the Suez Canal, in Egypt, which connects the waters of the Red Sea, or rather those of the Gulf of Suez with the Mediterranean at Port Said. The project is chiefly due to the great French engineer, M. Ferdinand de Lesseps, and the Khedive of Egypt; as it is now the main highway of English commerce and traffic from the United Kingdom to India, a large amount of the shares of the canal is owned by the British government. The number of steamers passing through it in 1898 was 3,464, with an aggregate tonnage of over nine million tons. Its annual revenue to-day is close upon $20,000,000. The other chief European canals are the Baltic or North Sea (Kaiser Wilhelm) Canal, with a yearly traffic numbering about 14,000 vessels; the Elbe and Trave Canal, opened in June, 1900 (41 miles in length), forming an additional waterway between the North Sea and the Baltic; the Dormund-Ems Canal; the Corinth Canal; and the Manchester Ship Canal ($35\frac{1}{2}$ miles in length) connecting the Mersey with the Manchester docks. Many other canals in Europe are under consideration, such as the Sheffield Ship Canal, the Bruges Canal, the Black Sea and Baltic Ship Canal, the Forth and Clyde Ship Canal, the Marseilles and Rhone Canal, etc.

The oldest canals in the U. S. are the Hadley and Montague, built in Mass. in 1792. The Middlesex, which joins Boston Harbor to the Merrimac River, dates from 1808. The Erie, by far the largest in the country, was for its day a considerable enterprise. It connects the Hudson at Albany, N. Y., with Lake Erie at Buffalo, is 352 miles long, and cost $50,000,000. Washington projected the Chesapeake and Ohio Canal to improve the navigation of the Potomac River and connect that stream with the Ohio River. Its construction was begun in 1828, but by 1850 it had only been completed from Georgetown, D. C., to Cumberland, Md., 184 miles, and from that point westward the enterprise was abandoned. It reaches, by means of 74 locks, an elevation of 609 feet. The Schuylkill Coal and Navigation Canal, from Mill Creek to Philadelphia, Pa., was completed in 1825. The Lehigh Coal and Navigation Company's Canal, from Easton to Coalport, Pa., is another important local waterway. In the early days of public improvements, two great canals were built in Ohio, extending from Lake Erie, at Cleveland and Toledo respectively, to the Ohio River. These canals have always been owned and operated by the state. Of late years the receipts for tolls have shown a constantly increasing deficit. Portions of them have been abandoned; and it is more than probable that in the near future they will be entirely displaced by the railroads.

TO SUCCEED IN RAILROADING

By JAMES J. HILL
President of the Great Northern Railway

RAILROADING is the most important industry in the United States. It employs more men than any other, with the exception of farming. It represents a greater invested capital. It is more essential to the existence of business and society. There are over a million employees on the pay-rolls of the various companies, and this enormous army is growing at the rate of over fifty thousand a year. During 1900, 54,366 new recruits entered the service. The year before that 111,000 new men were employed, owing to the sudden increase in the volume of business that came to the railroads as a result of the great prosperity. With the large increase in the number of railroad employees, there has come a corresponding increase in rewards, and in salaries paid, and few industries to-day offer better opportunities for the right sort of men. But in order to win a place at the front they must be the right sort of men.

The average man, while he may gain a very comfortable position, cannot hope for one of the great prizes, because, where such a vast number of men are employed in a business, the competition is necessarily very keen.

The qualities needed in the railroad business by the man who desires to succeed in a large way are the same as are required in most other spheres of activity. They are application, industry, a clear head, and imagination. It is imagination that provides forethought—the ability to look ahead, to take advantage of all possible business openings, to secure an extension of business and a development of new territory. No other single trait is so important to real progress as this, but it must be an imagination well-balanced and reinforced by good judgment and a willingness to work morning, noon, and night. Railroading is peculiar, in that there are constantly arising emergencies which demand long stretches of continued service. Plenty of instances are on record where men have been compelled to work for thirty-six consecutive hours, and they can do this only when they have an interest in their work. Mere perfunctory labor may hold a job, but it will not push a man forward.

There is little in ordinary routine railroad work that fits an employee for responsible positions where brains are required. There is nothing in turning a brake-wheel or clicking a telegraph instrument or collecting tickets that is in itself of any particular value as an educational measure. Experience in doing these things will undoubtedly make a man more proficient in work in one of these particular branches, but when it comes to advancement to an executive place it is different. There the great foremost consideration is brains. Every railroad in the country is constantly on the lookout for brains, and whenever a man of exceptional ability is found, he is eagerly snapped up and is pushed forward as rapidly as possible. From office boys to conductors, all are closely watched by their superiors for traits that give promise of ability. The demand for good executive skill in railroading is far ahead of the supply, and there is no business that offers surer advancement to the right sort of boy or man. No one need fear that he will not be given an opening if he is fitted for higher work. The industry is growing by leaps and bounds. It feels the impetus of prosperity in every trade, and with the enormous development that has come and that gives every promise of continuing, the growth promises to be even greater in the future than it has been in the past.

In some respects there have been decided changes in the methods of railroading. The industry to-day is still very young. There are men active in the world to-day who were alive when the first railroad train was sent over American rails. Consequently, the business is still in a formative state, though it has about come to a fixed basis. When rail-

roads were first built, the men then engaged in the transportation business, the captains of canal boats and managers of stage routes, naturally drifted into this new line. They brought with them their canal boat and stage route ideas, and these came to be the foundation of railroad management and usage. The result was that there grew up a narrow system which retarded growth. It was out of this that there grew what is rapidly coming to be regarded as a superstition — the idea that a man made a good railroad executive because he had started in as a brakeman, or a conductor, or a station agent, or a telegraph operator, or in some other position that had to do, in one form or another, with the hauling of freight or passengers.

It is now well recognized that much more than experience in one of the lower grades of the service is needed to equip a man for a responsible office. In fact, the progressive railroad manager realizes that in many cases men entirely outside of the business, who have brains and industry and a willingness to learn, are often more valuable than those in the service. Preference, however, is naturally given to service men, and the safest way to reach a good position, in fact the only way as the business is now constituted, is to start in at the bottom and trust to the exhibition of the necessary qualities for advancement. A man at the head of the railroad naturally looks among his employees for assistants. A man may be a very excellent grocery clerk, or the best sort of bricklayer, and have in him all the material that goes to the making up of the railroad man, but he can hardly hope for an opportunity to demonstrate this while he sticks to clerking in a grocery store or to laying bricks. He has to get under the eye of railroad men if he wants a railroad job. But once on the pay-rolls, no matter how humble his position, he can rest assured that if he has the right qualities he will be given opportunities to show them. This does not necessarily mean, of course, that he will succeed. Even if he has the best intentions in the world, and supplements them with the most dogged perseverance and resistless energy, he may never get beyond a certain point, because he is not fitted by nature for further advancement. That is his misfortune. Others again, perhaps with exceptional endowments, start wrong and get into a rut. They, too, will find progress blocked beyond a certain point, because nowadays railroading demands an original mind. There are a great many instances on record of men who advanced well to the front, reaching in some cases the presidency of roads, but who finally came to grief because their minds were one-sided, and they were never able to get out of a certain line. The man who is content to do merely the work before him, even though he does it well and thoroughly, is the sort who will come to a standstill very early so far as advancement is concerned.

Modern railroading demands of its executives a thorough knowledge of the business, from the ground up. To further this knowledge, a system has been instituted that gives the most promising employees rare opportunities to master the details in all the branches. Such employees — and many of them are found among the office boys, while at the other end a considerable number are taken from among the ranks of conductors — are put at the work of distributing accounts. This is a cross between bookkeeping and compilation of statistics. In every railroad, the outgo of money is in two channels, either for labor or material. Every dollar expended comes under one or the other of these heads. The man who traces this outgo is bound to become thoroughly familiar with every branch of railroad work, from construction to transportation. It is thus that the most liberal education to be obtained in the business comes through the work of distributing accounts. For example: The pay-roll of the section-boss ordinarily gives only the item, so many days' work by so many men. This is ordinarily accepted as the final entry. In the corporation run on exact principles, the account is carried further. Careful computation is made to see what each pay-roll represents in the way of work accomplished; so many ties laid or renewed, so much track raised, so many acres of weeds cut, and so on. Thus the young men who distribute these accounts learn exactly what it costs to lay or renew a certain stretch of track, to care for a mile or a half-mile of road. They know what can be accomplished with every dollar expended on this work. They know what they have a right to expect from a man in charge of a gang of laborers in the shape of work accomplished. They can make an exact computation of the expense involved, and thus become valuable supervisors when they are placed in positions of executive responsibility. Instead of guessing, they know, and absolute knowledge is more essential to successful railroading than to almost any other business in the world. It is on the railroad where there is no guesswork that the best results are obtained for stockholders. If a boiler is built in the shop, the accounts are distributed so as to determine the exact cost of driving every rivet, with the result that the man who handles these accounts, if he is good for anything, knows at the end of his term exactly what it costs to build a boiler, and how many boilers a man in charge of a shop should turn out with a given amount of labor.

With every department, large and small, the same plan is carried out. The result is that by the time the men who have been picked out to distribute these accounts have been at work a year, they know, or will know if they are the right men for the place, the workings and requirements of one department as well as another; how the work of the entire road ought to be conducted, and what the officials have a right to expect of their subordinates for the money paid out for wages and material. A year of

this training is considered sufficient. At the end of that time the men engaged in it are put at practical work. It is recognized that, after all, the accounts are but a shadow of the substance; that they inculcate the theory, and that too much theory is liable to be dangerous. Experience has shown that twelve months is quite sufficient to give men who have it in them to go ahead, a full mastery of the knowledge of details required. The graduates of this system, at the end of this period, are generally put in as assistants to division officials, where they have charge of the office accounts. Now and then an old-fashioned official will be found who has no very warm welcome for the new-comer, fearing probably that, with his more exact and scientific knowledge, the youngster will soon work into first place. Where this is the case, all the difficulties possible are put in the way of the young man, but the system soon finds its own level and the man who obstructs it soon sees his error. The policy of obstruction is at the best a clumsy policy, and, while it may succeed in maintaining an incompetent man for a little while, in the end it puts him out of the way.

The necessity that men in charge of a railroad property, or any of its divisions, should know their work thoroughly, is imperative if sound results are to be obtained in operation. Too much specializing in the past has been one of the most prolific sources of trouble in preventing the running of railroads on a paying basis. In a business where a single cent tacked on certain items means millions of dollars in the aggregate, general knowledge on the part of responsible heads is necessary. It is not sufficient to know that a locomotive can haul a given amount of freight, or a certain number of passenger cars, over a given division, at a certain cost; it is necessary to know practically what every foot of the haul costs, so that all the existing conditions can be made the most of, and, wherever necessary, new conditions be created. A difference in grade between two competing lines may mean the difference between bankruptcy for the one and prosperity for the other. This, known in advance, will determine effectively the original construction and building of extensions, and may often determine the rebuilding of long stretches of road, to the great profit of the owners. Some railroads in this country can haul freight between two points at a given figure, pay all expenses of operation, and declare a good dividend. The same figure on other roads will not more than pay the actual cost of the haul, returning no profit whatever. The result is that in case of a falling off in business, the one set of roads can flourish, while the others go into the hands of receivers. The difference is that one set of roads was built right, and the other wrong; that one set is on a sound basis and the other is not. The properly trained railroad man will appreciate this difference and be in a position to handle his property accordingly.

The same necessity as to knowledge of original construction applies to a knowledge of all the details of transportation. To be properly equipped, the young man who seriously takes up the railroading business should have at his fingers' ends the fullest information regarding the minutest details. And more than this, he should prepare for himself a solid foundation by acquiring a broad general education; not necessarily a college education, but an education, nevertheless. A man need not necessarily go to college to be educated. If the opportunity to devote three or four years to a higher course at one of the universities is denied him, he can very well supply the deficiency by the right sort of reading and enough of it. Biography, books of travel, history, and other books along these lines, books that have in them something that will repay the time spent in their perusal, will give him all the learning necessary to bring him to the front and keep him there, if he belongs at the front. The trouble with most young men is that they quit studying when they quit school. Any leisure time they may have they devote to social dissipation, instead of giving a fair proportion of their time to the task of keeping in touch with the literature and news of the world. Nothing is more inspiring to the earnest man than the reading of history, especially those periods of history that deal rather with the industrial and moral and mental development of the people. These sections are much more important, both to the student and to the business man, than the sections dealing with wars and tragedies. Wars may be necessary, but they rarely carry a lesson that is of any practical value to young men who are in the world to-day, and who have their own way to make. We are living in an era of peace, and as the world moves on we will get farther and farther away from the false ideas that in times past so readily precipitated war. The great matter now is to prepare for the conquest that comes with commerce and trade. About the most important thing for the aspiring young man to do is to cultivate individuality; to think and act for himself. In this connection, he will find it the part of wisdom to avoid associating himself with labor unions. Many excellent men have come out of these unions and many excellent men are still to be found in their ranks, but their tendency on the whole is not a healthy one: it is leveling rather than elevating; it pulls the great body of working people down to the caliber of the least intelligent and deserving, instead of bringing the latter up. The man who is content to be one of many, to maintain the position of a follower rather than a leader, is not as much injured by association with a labor union as those who are ambitious to make a distinct success. Unionism, and the rules and regulations that are its bulwark, do not favor the sort of ambition that every American boy is supposed to have when he starts out in life. The successful men,

almost without exception, are the ones who strike out on individual lines at the outset. They learn to depend upon themselves. They cultivate their own strength. This is as true to-day as it was yesterday, in the railroad business as well as in any other.

TRAINING RAILROAD MEN

By WILLIAM M. GARRETT
Superintendent of the New York Division of the Philadelphia and Reading Railroad

THE Philadelphia and Reading Railroad has a most carefully worked out system of training its employees. With the presentation of the application for employment, a man is rigidly examined as to his physical fitness for the service, and the senses of sight, smell, and hearing are thoroughly tested. Approved of by the medical examiner, the

applicant goes before the time-table examiner, to receive instruction in the first principles of railroad service, with hand lantern and fixed and movable signals. Well taught, he is able now to pass the examination preliminary to actual railroad work.

Eager for more knowledge, he is given employment on the line under the best train conductor, if that be his branch of service, or with the

best engine man if he be on engine duty. These men, who are actually in charge, are fully capable of giving him the most valuable instruction, and have it as part of their duty to compel him to become proficient. Satisfied as to his ability, from the reports of his instructors, the officers of the road give him regular employment, but make it an obligation upon him that from time to time he call upon the train-master, road foreman, and time-table examiner for additional information. The supervising officials are thus enabled to satisfy themselves that he understands not only his immediate duty, but the calls which may be made upon him in the future. It is the test of his ambition, as well as of his intelligence; and a record is kept in the superintendent's office for reference as to his capacity and promise.

He is a railroad man now, the working part of a great machine. Every detail of his quality in the performance of his duty is laid strictly to his account. He is in a position to understand thoroughly the rules that have been laid out for his guidance. He knows he will be called to answer for an error of judgment, as well as for a dereliction in duty.

There is a thorough investigation of every case of violation of rules. Some of them are of small moment, others of major importance; but, in all, exactitude of inquiry, strict accounting for fault, and every measure which can make the good man better or eliminate the incompetent man, come into inexorable service.

Let us suppose that a real accident of serious nature has occurred. The inquiry is made on the spot where it actually happened. The employees concerned are required to place themselves, as nearly as is possible, in the positions which they occupied at the time the accident took place. Any irregular practice, any disregard of rules, any failure of discriminating judgment where rules do not directly apply, is instantly brought to light. No man is deprived of the benefit which an investigation should give; and, if his mistake be a minor fault, he is expected to profit, and profit well, by the object lesson he receives. Causes of accident, carefully investigated, serve as the basis for the formulation of rules which guard against the recurrence of a similar complication. Discipline may demand dismissal. The dismissal of a railroad employee, merely by personal notification and a dropping of his name from the rolls, has only negative value; it is nothing more than the removal of a source of danger. But dismissal as it is enforced here acquires a positive value, in that it serves as a caution and a guide to all other men who seek to carry out the spirit as well as the letter of the company's orders. Bulletins are posted announcing that —

"Freight trainman —— —— has violated flag rule Number 99. He is no longer in the service."

The necessity of a personal reprimand is avoided; and every other man on the line has learned that the reason for this particular dismissal is to be found in this particular offense. He takes the lesson to heart unfailingly; and his normal balance with regard to all other rules, which his good sense tells him must be observed without detriment to the observance of Rule 99, remains undisturbed.

I am dealing now with good railroad men, not bad ones. It is the question of advancement, and not of dismissal, that is to be fully considered. Before a man is promoted, his record is carefully reviewed. He is a brakeman, let us say. The place of signal-man, with additional salary — and additional responsibility — awaits him. Before he can claim the salary, and before he can attain the honor of the responsibility, a rigid examination must be undergone in the office of the time-table examiner. Perhaps he fails. But he has been a good brakeman; he is permitted to return to his old duties. The next time he is examined, he knows his new responsibilities, and he knows them thoroughly. He comprehends the true meaning of a train's right of way over a single track under all conditions, and his examiner impresses it so thoroughly upon him that even on his first day of fresh employment, the information he has acquired is applied instantly, firmly, and correctly.

No fireman rises to be an engineer unless his lesson has been learned as thoroughly as that of the trainman. But before him there is an additional examination in practical mechanics, conducted by the road foreman, who assures himself that the candidate understands thoroughly the handling of an air-brake, the making of all repairs, and the fit means of meeting any emergencies which may develop.

Even with good men, there is the possibility of oversight. A voluntary fault is one to be punished; an involuntary fault is one to be corrected. Men of the grade of intelligence and of the grade of morals which railroad service demands, deserve absolute justice at the hands of superiors. A clear record means much for the condoning of error. There is not a man on the road who does not know that, with his record clear, a different measure of discipline will be vouchsafed to him from that which is meted out to the careless, indifferent employee. As a rule, the endeavor is made to discipline a man without suspending him. The violation of a rule, or gross irregularity in train handling, brings upon the offender a reprimand for his ears and a blemish for his record. He loses no money for his first offense, if it be slight; his family suffers no privation; and he remains the corrected man who has not been publicly disgraced. The effect upon the men of such caution in the exercise of punitive power, causes steady improvement in the general *morale*. They know that all irregularity in the performance of duty is charged against them on their records; they know that unless those records pre-

sent emphatically redeeming merits, habitual negligence will force them wholly from the service. They know that they are being treated as men, fairly and honestly, and that, as nearly as human oversight can provide, their merits and their demerits are balanced carefully in the scale. Employees, as well as operative officials, are impressed with the importance of reporting to departmental heads any services which, specially commendable, may range from quick discernment under trying conditions to economy of material in the day's regular work. A good man, on whom has fallen the misfortune of serious accident, is permitted to continue service without discipline other than that which is embodied in a personal reprimand, and the exaction from him of a promise that he will do all in his power, through faithful performance of duty, to make good the loss the company has sustained.

From time to time, the officials of the road who are in charge of trainmen and enginemen assemble employees of these classes and discuss with them the handling of all trains. Examples of irregular practice are quoted by the official in whose department they have occurred, although no mention is made of the man who was responsible.

"What action," the official asks, "would you have taken under similar conditions?"

It is like a class-room. The interrogated rises to his feet. He is on his mettle. His fellow-workmen, experts, all, are round about him. He makes a reply which shows, to the full, his knowledge of practical railroad work, and serves as an elucidation of this particular problem for every one in the room.

Twice every month bulletins are displayed, asking of enginemen and conductors their opinions and their intelligent comment upon particular train orders or upon the handling of certain trains. It is practically a written examination, held once a fortnight; and it is an examination, not alone as to the knowledge the men possess, but as to the amount of interest they have in their vocation and in the welfare of the road. The replies, carefully filed after study by the time-table examiner, are put down to the credit of the men who have displayed this necessarily real interest in their employment. There is, in addition, a general vantage gained. All the employees have discussed the subject-matter of the bulletin; the possibility of a misunderstanding has been absolutely eliminated. Whatever unusual feature the new order has presented, has been comprehended in its consequences, as well as in its origin. Wherever an employee has shown in his comment that he did not understand clearly the intent of the bulletin, he is summoned by the train-master and receives an adequate verbal explanation. When all replies have been received, an advisory notice, in which the original bulletin is quoted, is posted on the board. Every man has his opportunity for a thorough

understanding of the subject. The advisory bulletins, laid out as they are with an eye to all the minds at which the original bulletin was directed, have been found to be one of the most valuable educational features at the command of operative officials at the present day.

As the duty of faithful performance rests upon the practical railroad man, so does the duty of recognition of meritorious work rest upon the official. Department masters must be recognized by railroad employees, who have at heart the interests of the company as well as of themselves, as officials who are actuated solely by a spirit of fairness and are as ready to encourage them for well-doing as they are to point out shortcomings. The official who does not display an appreciation of intelligent and faithful service can never expect his subordinates to meet emergencies in the true spirit. He must discipline properly a wilful disregard of instructions; yet he must be as careful in his preliminary investigation as if the offender were himself. Were the orders disregarded wilfully, or did the memory lapse? For each there must be a different discipline. Pressure of duty might cause an oversight in one particular. The error is not a fault, properly so termed, either of commission or omission. The man deserves an admonition, not a rebuke.

In time past, the services of many good men have been lost to indiscriminating roads because of unwise punishment for unintentional error. Not so in the practice school, where justice always governs. It may be taken for granted that no railroad man will ever voluntarily give occasion for an accident. Every consideration, therefore, when an accident has occurred, should be studiously regarded. The condition of the man before he took his train out upon the line is to be analyzed and noted. Account is to be made of the hours he gives to sleep; of the condition of his domestic affairs, and of many considerations which would ordinarily appear to be personal to him alone. It has happened again and again that when some first-class trainman and engineer has had a serious accident, he was unable to explain why his mind did not grasp in time the danger of the situation, and indicate at once the course to be pursued. Investigation brought out the circumstance that another thought, another anxiety, had intervened at the critical instant and had weakened the concentration of the intellect upon the duty nearest to his hand. Men such as these, their past records testifying to their merit, prove better workmen in the future; their fault becomes their safeguard.

The sum of all this care, of all this study, of all this observation in the school of practice, means proficiency. The young man with a clear head, the sure spirit, and the strong ambition, has become the efficient railroad employee. His reward is at his hand. His reputation clear, his intellect undimmed, his energy unimpaired, he need never lack employment. His every-day training out on the line educates him in the

highest practical knowledge of the operation of a road. All railroads recognize now the standard rules formulated by the officers of the American Railway Association. A man working in the East observes rules which are observed in the West. If he is a good workman in the North, he can secure employment in the South. Trained, he has an advantage over the untrained; and everywhere he is recognized as the expert in his line.

Beyond him lie administration and finance. For such posts he never has been examined. But the history of railroads is filled with examples of men who have gone from road-bed machinery or train service to the superintendent's office; from superintendence to administration; and from administration to finance.

The higher places await fresh manifestations of the intellect and of the ambition.

POSSIBILITIES OF STREET RAILROADING AS A PROFESSION

By EDWARD E. HIGGINS

A GREAT world-industry has arisen within the last decade, and has grown so rapidly from its modest beginnings that we rub our eyes with amazement when we stop to think of the differences between the life in city, town, and country, to-day and that of ten or fifteen years ago, before electric cars began to hum through the streets and country roads. The science of municipal transportation in all its branches is now being eagerly studied by the brightest, keenest minds of three kindred professions,— civil engineering, mechanical engineering, and electrical engineering,— while there has arisen an urgent demand for good executive men, capable of assuming the larger and smaller positions in the operation of the great city properties which are being formed by consolidations, and of the innumerable systems of small lines linking together cities and towns.

Not in America only, but abroad as well, electric railways are being built so rapidly as to make it certain that the growth of the industry during the past ten years is as nothing compared with what will come in the next twenty-five. America is so far leading the world in electric railroading that foreign syndicates are constantly sending here for men who understand the business, and if a bright, wide-awake American, with brains and energy, is prepared to drop ease and home comforts,

take his carpet-bag in hand and become a soldier of fortune in the world,— going, when called upon, to South Africa or China, to Patagonia or Hawaii, to Russia or India,— large salaries and opportunities for investment profits may well be hoped for.

What limit to ambition is there, then, in this field? What chances are there to-day for the men in the ranks? What inducements does street railroading hold out to those who are on the threshold preparing to choose their life-work, and how can the first step best be taken? These are a few of the questions which I will try briefly to answer.

There are, generally speaking, five classes of men required for street railway operation: first, the transportation force; second, the mechanical force; third, the engineering force; fourth, the accounting force; and fifth, the leaders and directors. The easiest position to obtain on a street railroad, for any one physically strong and in good health, without special manual training, is that of motorman or conductor. There is always a demand from both city and country for honest, reliable, «steady» men, who can be depended upon to fulfill their daily duties with intelligence and devotion. The force of «car service men,» as the conductors and motormen are usually called, forms the bone and sinew of the organization, and the trustworthy and ambitious worker may easily obtain recognition and advancement from his immediate superiors.

Conductors and motormen are paid from $1.75 to $2.25 per day in cities, and in country towns from thirteen to eighteen cents per hour. The candidate for a position on a large street railway is first put in training for a week or two weeks without pay, and his capabilities are carefully tested. If accepted, he enters the service of the company on the «extra list,» so called, and for a few weeks or months, as the case may be, must be on hand within certain hours, prepared to take out a car in the place of a «regular,» who may be ill or away from duty, and to handle the extra cars during the «rush hours.» He is paid by the trip or hour, and can frequently make as an «extra» nearly as much as the regular man.

The next step comes when he is given a regular run, usually one of the least desirable as regards hours of service. As he grows in the confidence of his superiors, he is given better runs; and, at the end of one, two, or three, years of service, he is, on many roads, given an increase of wages, together with «service stripes» (to be worn on the sleeve of his uniform), which indicate the length of time he has been in the company's employ.

The chief qualifications of the motorman are courage, strength, endurance, and trustworthiness. The chief qualifications of the conductor are absolute honesty, courtesy, and never-failing patience. The success of a street-railway company in winning traffic is due far more to the conductors and motormen in its service than is generally understood or be-

lieved, and the two men on a car can so handle it by intelligently looking out for business as to bring to the company larger receipts than others on the same line, and to win for themselves gratitude and appreciation from passengers. The officers of the company will surely find this out, and will mark such men for promotion.

Advance from the ranks of the car-service men may be along several lines, dependent largely upon a man's education and general intelligence. The immediate step above the motormen and conductors is, on many systems, to the force of "inspectors," so called, whose duties are varied and interesting. An inspector may be sent this morning to find out why a competing road is getting the business of Riker Avenue, which rightfully belongs to his own company's line, and to make recommendations to the superintendent as to how the lost traffic may be regained. To-night, he is one of a force of twenty or thirty of his fellow-inspectors detailed to handle the theater traffic, which comes down in a rush upon the cars in a single half-hour at the close of the evening's performance. To-morrow, he may go to Bethany Church to make inquiries about some Sunday school picnic which has to be taken to the country and called for on its return, and he must see that cars enough are provided to handle this special "business," coming and going. In short, the inspector has enough variety in his life to make it interesting, together with wages of from $15 to $20 per week, in the larger cities.

From the ranks of the inspectors, the chief inspector and his assistants are chosen, and, on large systems, the office of chief inspector is a very important one, as he comes in constant daily contact with the general manager, where his qualities for higher work may be understood and appreciated.

The division superintendents, or foremen, as they are sometimes called, are chosen either from the car-service force directly, or from among the inspectors. The division superintendent runs the cars of a section of the entire system, subject to the orders of the general superintendent.

The qualities which the division superintendent should possess are a capacity for hard work — absolute devotion to that work, a sense of justice, freedom from prejudice or partiality in his treatment of the men, intelligence, and executive ability in the handling of routine work. On the smaller systems, a position of this kind will pay from $900 to $1,200 per year, and, on a larger system, from $1,200 to $1,800.

The general superintendent is at the head of the transportation department of the system, reporting to the general manager, and responsible for the entire car service. He is frequently an understudy for the general managership, and steps into the latter position when the manager becomes president or is transferred to another position. The salary

of a general superintendent will range from $1,500, on a small system, to $3,500 or $4,000 on the larger ones.

A man with a taste for mechanical and machine work, who likes to use his hands, and whose tastes do not run to the business end of the profession, may enter the repair and machine shops of an electrical railway, and in time attain the position of master-mechanic. If he is able to keep up the equipment of a road at a low cost, he will always be sure of an engagement, and will become an important and highly regarded member of the organization, at a fair salary — a salary of, say, $1,500 with a small road, to $5,000 with a large one.

The engineering force of a large electric railway consists usually of a chief engineer, who is a department head, and in close touch with the manager; his assistant or assistants; the engineers in charge of the power station; the steam and electrical plant, and sometimes an engineer of maintenance of way. The positions of chief engineer and electrical engineer call for men of professional training, and are rarely held by those who have not this training. Graduates of technical schools or colleges must usually, however, reach these positions by pushing through the ranks of dynamo tenders and station engineers, where actual experience with machinery, in addition to "book knowledge," can be obtained.

Considering the expensive training required, the engineering force of a street railway can hardly be called well paid. Station engineers in charge of the steam plant receive from two dollars and twenty-five cents to three dollars per day. These are the men who have "learned their trade" in practical work. The college and school graduates, set for the first time at manual labor, are fortunate if they can realize five to ten dollars per week at first, but their compensation comes in later, when, by reason of their theoretical groundwork, they are able to pass in the race many older men who are not fortunate enough to have this training.

Engineers who are notably successful in their handling of street railway properties may become the trusted counselors of capitalists and syndicates in large operations all over the world, and their services will always meet with due recognition on the part of those who use them,— for self-interest, if for no other reason,— for the man who obtains a reputation of never leading capital into losses is the man whom all capitalists are seeking. There are, for example, three or four engineers of international reputation in the street railway field, retained by great London and New York syndicates, whose fees run from $50,000 to $100,000 per year, amounts fully equal to those earned by the most successful lawyers.

To become a clerk in the accounting department of a street railroad

is to take a step which may easily, and many times quickly, lead to the position of auditor, secretary, treasurer, or comptroller; but special aptitude for figures and for the theory of accounting is, of course, necessary, if any such large results are to be achieved.

The comptroller of a large city railway is the confidential adviser of the manager, showing him by figures the results of experiments in policy, while his responsibility is usually coequal with that of the manager, being directly to the president and to the board of directors. He is in a position to watch the details and general results of operation; his judgment is trained in all departments, and he frequently develops ability as a manager. Another line of possibilities is open to him also. Capitalists considering the question of going into new enterprises always require expert examination of the properties themselves and of their books, and no one should be better able to do this than the man who has won their confidence as comptroller of one of their properties, or who has a general reputation for honesty and ability.

The prizes of this great profession of street railroading, the important positions which are in the public eye, are, it is true, open to all, but the man who is to succeed must start with a physique capable of enduring constant hard work, day and night, for years; he must be willing to make all necessary sacrifice of time and comfort; and, above all else, he must have an ambition which will stimulate and constantly outrun achievement. To such a man, no profession offers to-day better inducements or larger financial compensation, for electric railroading is "the modern idea" toward which the science of transportation is gravitating.

Arch.— A concave structure of bricks, stone, or wood, so arranged as to remain in place by the mutual pressure of the component parts, as well as to bear a weight above. It dates back to the time of the Egyptians, and has played an important part in architecture and engineering from earliest times. The sides of an arch are called *haunches* or *flanks* and the highest part is known as the *crown*. The uppermost of the wedge-shaped pieces is called the *key-stone*, the lowest is the *springer*.

Bridges, Longest in the World

The longest bridge to-day in the world is that of the Tay, in Scotland, and the next longest is also in Scotland across the Firth of Forth. Modern bridge construction has since the era of railroads been greatly developed, and is now, by reason of our superior steel manufacture, largely in the hands of American firms. Several new bridges have of late years been constructed in Siberia, for the Rus-

sian government, and many have also been built in British India, while some new ones are contemplated; among these projects are one to be erected over the River Takolo, in the French Sudan; another is designed to cross Sydney Harbor in New South Wales; while others have been recently constructed in Europe to cross the Rhone, the Moselle, etc., and one is contemplated to bridge the arm of the sea at Jutland, Denmark. The following gives the length of the chief bridges in various continents:—

	METERS	FEET
Tay, Scotland	3,200	9,696
Forth, Scotland	2,394	5,552
Moyerdyck, Holland	1,470	4,820
Volga, Russia	1,438	4,715
Weischel, Germany	1,325	4,346
Thoen, Germany	1,272	4,172
Grandenz (Elbe), Germany	1,092	3,580
New East River Bridge, Brooklyn, N. Y.		2,202
New East River Bridge, length of main span, between the towers		1,600

Cantilever.— A term applied in engineering to the part of a beam which projects out from a wall or parapet or beyond a support. In a bridge in which the principle of a cantilever is applied there is usually a trussed bridge of two portions, reaching out from opposite banks and supported near the middle of their own length on piers which they overhang, thus forming cantilevers which meet over the space to be spanned or sustain a third portion, to complete the connection. A beam supported in the middle is said to have two equal cantilever arms. Another principle of the cantilever is seen in a balcony in front of the windows of a house which is supported by brackets or projecting cantilever beams. In architecture, the brackets to support this balcony, a cornice or the like, is called a cantilever, as is also a supporter of the roof timber of a house.

Chain Bridges are suspension bridges supported by chain cables, that is, by separate links of wrought iron or steel pinned together so as to form a chain. They are used only for light traffic; such was the chain bridge at Little Falls, near Washington, D. C., which has given place to an iron truss bridge, erected in 1874. Several are still in use in England, but mainly for passenger traffic. In this era of railways and great engineering exploits, bridge construction has become a most important art. We have departed far from the primitive structures of timber or of stone of early times, and the necessities of commerce and the vast development of railway traffic have called into existence every resource of the skilled engineer in bridge construction. The types are almost numberless of these useful structures, from the mammoth undertakings, such as the New Tay bridge

and the Forth River bridge in Scotland, with a length respectively of 10,780, and 8,295 feet, the Quebec bridge, over the St. Lawrence, the Ohio and the Missouri River bridges, and the new East River bridge at New York, to the elementary arched masonry and timber bridges of ancient times. The chief types to-day are the cantilever, truss, suspension, and tubular bridges, of more or less length of span, and immense bearing power. The enterprise of colossal and rapid bridge building has of recent years been almost monopolized by American engineers, in consequence of the abundant supply and great strain-bearing qualities of the steel manufactured in this country and the expertness, we had almost said the audacity, of American engineers and mechanics.

Eiffel Tower.—An iron framework tower, in the Champ-de-Mars, Paris, in the form of a concave pyramid 984 feet high. The lantern is fitted for meteorological observations. It was built by Alexandre Gustave Eiffel for the Exhibition in 1889.

Horse-Power is a rate of doing work equal to 550 foot-pounds per second, or 33,000 foot-pounds per minute. The foot-pound is the unit of work, and it represents the amount of work, or energy required to raise one pound vertically through a distance of one foot. The same amount of work, namely, three foot-pounds, is done by raising one pound through a vertical distance of three feet, or three pounds through a vertical distance of one foot. The difference between steam horse-power and electric horse-power is in the difference in the nature of the power. To explain this will require the use of an electrical dictionary, containing tables of compilation: the unit of electric horse-power is «the watt.» The energy or work is the «volt,» «coulomb,» or «joule,» and measured in foot-pounds is equal to 737,324 foot-pounds. The volt, coulomb, or joule is, therefore, the unit of electric work just as the foot-pound is the unit of mechanical work. One electric horse-power is a rate of doing work equal to 746 watts or 746 coulombs per second. The ampère is the practical unit of electric current; the ohm is the unit of electrical resistance—such a resistance as would limit the flow of electricity under an electro-motive force of one volt to a current of one ampère, or to one coulomb per second. «K. W.» is the contraction for Kilo-Watt, meaning one thousand watts.

St. Paul's.—A famous cathedral in London; founded in 1675, on the site of an older cathedral. Designed by Sir Christopher Wren.

St. Peter's.—The largest and grandest temple of worship in the world is St. Peter's Cathedral at Rome. It stands on the site of Nero's circus, in the northwest part of the city, and is built in form of a Latin cross. The total length of the interior is 613½ feet;

transept, 446½ feet; height of nave, 152½ feet; diameter of cupola, 192 feet; height of dome from pavement to top cross, 448 feet. The great bell without the hammer or clapper weighs 18,600 pounds, or over 9¼ tons. The foundation was laid in 1540 A. D. Forty-three Popes lived and died during the time the work was in progress. It was dedicated in the year 1626, but not entirely finished until the year 1880. The cost in round numbers is set down at $70,000,000.

Thought, at What Rate Does it Travel.—One hundred and eleven feet per second, or about a mile and a quarter per minute. Elaborate experiments have been made by Professors Helmholtz, Hersch, and Donders, to ascertain the facts on this question, the result of which was that they found the process of thought varied in rapidity in different individuals, children and old persons thinking more slowly than people of middle age, and ignorant people more slowly than the educated. It takes about two-fifths of a second to call to mind the country in which a well-known town is situated, or the language in which a familiar author wrote. We can think of the name of the next month in half the time we need to think of the last month. It takes on the average one-third of a second to add numbers containing one digit and half a second to multiply them. Those used to reckoning can add two to three in less time than others; those familiar with literature can remember more quickly than others that Shakespeare wrote "Hamlet." It takes longer to mention a month when a season has been given than to say to what season a month belongs. The time taken up in choosing a motion, the "will time," can be measured as well as the time taken up in perceiving. If it is not known which of two colored lights is to be presented, and you offer to lift your right hand if it be red and your left if it be blue, about one-thirteenth of a second is necessary to initiate the correct motion.

Tugs.—One tug on the Mississippi can take in six days, from St. Louis to New Orleans, barges carrying 10,000 tons of grain, which would require seventy railway trains of fifteen cars each. Tugs in the Suez Canal tow a vessel from sea to sea in forty-four hours.

Tunnel.—An underground passage, usually through a mountain or beneath the bed of a stream, for transportation purposes, or the conveyance of water. The first tunnel in the United States was constructed in Pennsylvania, for the Schuylkill Navigation Company's Canal; completed in 1821. Among the world's notable railroad tunnels are the Hoosac tunnel, through the Hoosac Mountains, in Massachusetts, nearly 5 miles long; the St. Gothard tunnel, through the Alps, 9⅓ miles long; the Arlberg tunnel, under the Alps, 6⅓ miles long, and the Severn tunnel in England, over 4 miles in length.

Typewriter, Who Invented it.—The first attempt at the construction of a machine that would do the work of the pen was that of an Englishman, Henry Mill, who, in 1714, took out a patent for such an instrument. The next recorded patent for a typewriter was granted in France, in 1841, to a blind man, Pierre Foucalt, whose machine being found practicable was used in several institutions in Europe. The first patent for working a machine upon the type-bar principle was that of A. H. Beach in 1856. The first practical machine was invented in 1867 by C. Latham Sholes, an American, assisted by S. W. Soulé and Carlos Glidden. Soulé and Glidden left the concern long before the invention was fully worked out, so that the real credit in the matter belongs to Sholes, who persevered in the enterprise from 1867 to 1873, when he took his machine for manufacture on a large scale to Messrs. E. Remington and Sons, gunmakers, of New York, who put it upon the market as the Remington typewriter. For the further improvement of the machine, Sholes was still largely responsible, for his services were retained by the firm until the time of his death, which happened only a few years ago.

Wonders of the World.—The "Seven Wonders of the World," so called, are given as follows: The Pyramids of Egypt; the Mausoleum built for Mausolus, by his queen, Artemisia; the Temple of Diana, at Ephesus; the Walls and Hanging Gardens of Babylon; the Colossus at Rhodes; the Ivory and Gold Statue of Jupiter Olympus; and the Watch Tower built by Ptolemy Philadelphus, king of Egypt.

GEOLOGY

Geology is the science which treats of the history of the earth, as recorded by the rocks and the agencies which have produced the changes and the development of the earth.

It includes the study and observation of the forces that have been, and are constantly, at work producing changes on the surface and in the interior of the earth. This forms Dynamical Geology.

It explains the composition of rocks, and treats of the way in which they occur. This branch is Structural Geology.

It evolves from a study of the materials and structure a history of the earth's formation, tells in what order the rocks have followed one another, how its land formations have originated and traces the growth of life upon our planet. This is Historical Geology.

The science of geology is proportionate to the immensity of the materials upon which it works and the agencies with which it deals. It is the dictionary of all the other sciences. The geologist not only

avails himself of, but is dependent upon, the students of the other branches of science. The chemist, the mineralogist, the astronomer, the physicist, the botanist, the zoölogist, and the geographer are all specialists working, in a sense, for him. He deduces the laws of the great world-making forces from the particulars and details which each of these supply.

For an explanation of the origin of the earth, the geologist is obliged to go to the astronomer. From that branch of science he gets the nebular hypothesis of the earth's formation. It is plain that there are many things in the study of geology that cannot be known with that thoroughness which science exacts from her followers, in all possible cases. Some things have to be supposed to be the case, and that supposition is called a hypothesis. This word is of Greek origin and means "upon this I take my stand." When a theory, or hypothesis, is advanced by anyone, it is criticized, tested, and examined, and students attack it to see if it will stand. There are many of these theories which have stood all tests and have come to be accepted as laws or facts. The nebular hypothesis of the earth's formation is based upon the observations by astronomers upon what they see going on around them in the other planets of the solar system which have not reached the development to which the earth has attained. It is supposed that all of the matter of the solar system was at one time a revolving mass of gases, which filled at least all of the space enclosed by the orbit of the most distant planet from the sun. This planet is Neptune and it is 2,800,000,000 miles from the sun. Therefore the least possible diameter of this mass of gases would be 5,600,000,000 miles. As these masses condensed, rings, such as those of Saturn, were formed and thrown off, to form planets, satellites, and moons. The remnant of this vast nebular mass is the sun at the center of the solar system. Upon this supposition, the earth was one of these condensed masses of nebula. In that condition, as it cooled, the outer crust of the earth being in contact with the cold temperature of space, which is supposed to be from 100° to 200° below zero, gradually cooled and condensed into a solid state of rocks. As it cooled, the waters which had previously existed in the form of vapor came in time to form the waters of the earth. They may have covered the entire surface. But the rocks were upheaved by the forces at work in the interior and land masses were gradually formed which divided the waters into oceans.

The condition of the interior of the earth is one of the hardest problems that the geologist has had to meet. This is because of the very slight data and knowledge upon which he can work. The deepest borings in the earth are not more than $\frac{1}{4000}$ part of the distance from its surface to its center. In this condition of lack of knowledge,

several explanations of the nature of the interior of the earth have been advanced. For a long time it was generally believed that the interior was a molten mass, and that only a crust of about fifty miles was solid. Few, if any, scientists hold that view to-day. That "thin crust theory" is almost wholly abandoned. Many geologists and most astronomers believe that the earth is practically solid to the center; but they allow for spaces of small extent which may be filled with molten matter. The astronomers have had much to do with deciding between this and the "thin crust theory"; for they have proved that the earth behaves in its astronomical aspects as a rigid body does and not as a hollow globe. A third hypothesis, which has many believers, is a sort of compromise between these two theories. It supposes that the mass around the center is solid, and that, between it and the outer crust is a layer of molten matter, not to exceed fifty miles in thickness. This is held to explain the rigidity claimed by the astronomers, and to satisfy the evidences of internal heat. The present imperfect state of knowledge renders it impossible to determine which view is correct.

Volcanoes.—A volcano is usually a mountain. But this mountain formation is an effect of the eruption and not a cause. The essential part of a volcano is the opening or crater. There are volcanic evidences all over the land surface of the globe. A volcano may be in a state of constant eruption, more or less violent; or it may be dormant for a longer or shorter period and then break forth again; or it may have had its day and then remain extinct forever. There are from 325 to 330 active volcanoes in the world. About 100 of these are on the mainland of Continents. The remainder are on islands. Two belts of volcanoes almost entirely encircle the Pacific Ocean; one extending from Alaska to Cape Horn at intervals; the other, a more continuous line, extends through Kamchatka, along the islands of the east coast of Asia, the South Pacific Islands, into the Antarctic regions where it unites with the American line. The third division includes those of Iceland, the Azores, the Mediterranean, Asia Minor, the East and West coasts of Africa, and the Indian Ocean. A volcanic eruption would seem to be primarily the struggles of a mass of imprisoned steam to escape. The steam, however generated, follows the line of least resistance and bursts through a weak place. The combustion and fire would seem to be an effect of the eruption and not a cause. The great masses of rock are expelled with such a force that combustion results from the friction and motion. Fragments of all sizes are driven out, from stones to lava and fine ashes and impalpable dirt. The volume of steam, when liberated, rises as a cloud in the air above. The lava runs in a molten state down the

sides until it cools and stiffens. Among the notable volcanic eruptions of the world are: that of Vesuvius in 79 A. D. when the towns of Herculaneum and Pompeii were completely buried in ashes and fragments; the eruption of Krakatoa in the Strait of Sunda, in 1883, was probably the most frightful on record. Not only was the island shattered to pieces and annihilated, but it was sunk over one hundred fathoms in the ocean; the explosion was noted by atmospheric disturbances even in Berlin ten hours later; ashes were scattered over an area of 300,000 square miles; depths of water over 100 feet deep were filled up; and the surface of the sea covered with pumice and ashes so as to impede navigation. These two were explosions in which inconceivable quantities of steam escaped, with tremendous violence. Mauna Loa and Kilauea in the Sandwich Islands were not explosive eruptions. They simply boiled over and the lava ran down the mountain sides in streams extending many miles. The lava escaped through the sides of the crater in fissures and often jet up to a height from 30 to 40 feet to 1,000 feet. Such eruptions are not accompanied by ashes or lava; but clouds of steam are always present. Geikie estimates that 99.9 per cent. of the cloud seen to rise over an active volcano is steam. The nature of the other gases present is indicated by the sulphur, alum, and common salt which are deposited by them.

Lava.—This is the name given to the molten streams which run down the sides of a volcano in eruption. It strongly resembles the slag from an iron furnace. It presents widely different appearances dependent upon its chemical composition and its rate of cooling. It is called basic lava if it contains large quantities of iron and metals. It is acidic if it contains a high percentage of silica or quartz. If it is glassy it is called obsidian. It is dark if it is basic; and light colored if it is acidic. If it cools slowly it is crystalline, if rapidly it is shapeless and glassy. If much steam or gas is contained in it, it is honey-combed and is pumice, which is sometimes so light as to float in water. Pumice is much used for polishing. The speed with which lavas flow down volcano sides depends upon the slope of the sides, and the consistency of the fluid lava. In one eruption it moved 3⅔ miles in the first four minutes. Its speed decreases as it cools. Sometimes it creeps for several months. The lava at Etna of the eruption in 1787 was still steaming in 1830. This slow cooling is an evidence that it is a poor conductor of heat. The front of a descending stream of lava rolls down hill, instead of flowing evenly; because of the friction of the earth on the bottom and the greater speed of the top. Of the two lava streams which flowed from the eruption of Skaptar Jokull in Iceland, in 1783, one was fifty miles long and twelve

wide; and the other was forty miles long and seven wide. Both were one hundred feet deep.

Fragmental Materials.—These include stones weighing many tons each, such as are seen for miles around Cotopaxi, in Ecuador, fragments varying in size from a walnut to a pea, and known as lapilli; fragments of lava sent whirling through the air and taking a rounded form from the rotation and known as bombs; cinders, called scoriæ; ashes and fine dust. The torrents of rain which follow eruptions wash the dust and ashes out of the air and form from it a species of mud, which, on drying, is called tuff or tufa. This often becomes so solid that it is used as building stone.

Causes of Volcanic Action.—This is a mystery to the geologist. No satisfactory explanation has been given of the source of the heat, or the presence of water sufficient to generate steam. One theory is that the high temperature is due to the original heat of the earth which it has not yet lost. Others hold that the giant forces at work in the interior of the earth, generate motion in the folding and crushing of enormous areas of rocks, sufficient to create the heat. Another theory explains the presence of steam by pointing out that nearly all volcanoes are near the sea, and that water passes through fissures and layers of rock by capillary attraction. Again, it is held that many substances have the power of absorbing great volumes of air, and that the steam was absorbed from the great vapor envelope which encircled the earth in its molten state. They hold that substances would absorb normal quantities under the great pressure of the superincumbent layers of matter, and by reason of upheaval or removal of pressure, this becomes liberated. Several of these theories will explain certain phases of volcanic action; but the science of geology has yet to find an explanation which will cover the entire field.

Earthquakes

Earthquakes have received so much study and attention that a science of earthquakes, called Seismology, has been founded. That term and the adjective seismic are derived from a Greek word meaning shaking. An earthquake is the transmission of elastic earth waves, which are manifested by a shaking or trembling of a part of the crust of the earth. Among the most notable of recent times is that of Lisbon in 1775 when 60,000 persons perished in six minutes. A marble quay upon which the people had crowded for safety was sunk 600 feet below the surface of the water. The attendant sea wave was 60 feet high at Cadiz. Ships in the harbor of Kinsale in Ireland were tossed about by the tidal wave which flooded the

harbor. Sweden, Africa, and the Great Lakes of North America felt the shock. While the geological effect of earthquakes is not so great as might be supposed, yet they often produce cracks or fissures in the earth which may or may not close again. Sometimes on closing, the earth on one side of the crack may be lower than the other. This produces an unevenness which is called a dislocation or fault. It is best seen in stratified rocks. One of the most violent earthquakes ever known in the United States was that in Owen's Valley, California, in 1872. The faults that were then produced have in many cases a displacement of 20 feet. In general the cause of earthquakes is some occurrence in the interior of the earth, sufficiently strong to be demonstrated by a series of elastic waves. These occurrences are: (1) an explosion of steam in volcanic regions; and (2) the yielding of the earth to strains of various sorts which are exerted upon it. The great earthquake of Charleston occurred at 9.50 p.m. of August 31, 1886, and lasted from 60 to 70 seconds. Its effects were very serious. The sidewise motion recorded was from 3 to 4 inches; and the wave of the shock traveled at the rate of 150 miles a minute. The disturbance was felt over an area of 2,500,000 miles; or within a circle having a radius of 1,000 miles.

Destructive Surface Agencies.—The chief surface forces that are continually changing the surface of the earth are: the atmosphere, running water, ice, lakes, the sea, plants, and animals. The effect of the atmosphere upon rocks is expressed by the term weathering, and this effect is brought about by rain, frost, changes of temperature, and the wind. If the rain were perfectly pure water it would have little effect upon rocks. But as the water-vapor in the air condenses it accumulates oxygen and carbon dioxide which increase the dissolving power of rain water, for nearly all rocks contain some ingredients which are soluble in water. As these dissolve out the rock crumbles away and in this way soils are produced. When granite which is composed of felspar, quartz, and mica, is acted upon by rain water the felspar is first dissolved out, the silicate of alumina forms clay or kaolin, the mica slowly disintegrates and the quartz remains insoluble in the form of sand. Iron compounds are rendered soluble through deoxidation by organic substances working underground. Sandstones crumble into sand; slates and shales form clay; limestone is almost wholly soluble in rain water and is slowly washed away by it. In this way rocks are gradually crumbled into soil and supply the deficiencies which crops cause. Rain, in a mechanical way, washes away soil, sand, and earth, in spite of the efforts of grass and sods to bind it together. The turbid, muddy condition of streams after a rain attests the amount of washing away done by the rain.

The freezing of water into ice is a great factor in surface destruction. This is due to the fact that when water freezes it expands with great force. Experiments in winter on the St. Lawrence River, near Quebec in Canada, showed the force of the expansion to be sufficient to burst iron bomb-shells with tremendous violence. As the rain water soaks down to fill up all of the minute cracks and crevices in rocks when it freezes it bursts the rocks into fragments. These by the action of repeated freezings roll down slopes. Fragments thus broken are called talus, and heaps of these may be found at the bottom of slopes a considerable distance from their original position. Sometimes during periods of intense cold rocks break up with a loud report especially in polar regions. The frost acts upon all sorts of rocks, regardless of their chemical composition, and thus prepares the way for the action of rain water.

Great pieces of rock are often split off by sudden changes in temperature. When rocks are exposed all day long to the intense heat of the sun they expand considerably under this influence. At night the radiation of heat is very rapid and a sudden contraction occurs which breaks up the rocks upon which it acts. This breaking is further hastened by the unequal expansion and contraction of the various substances of which a rock is composed. A very slow but none the less sure mode of disintegration is that produced by the action of the wind blowing fine sand against the face of rocks. In this way rocks are often polished to a high degree. Sometimes the softer portions of a rock yield first and the results are often fantastic. It is estimated that when rain falls upon the earth one-third of it is evaporated; one-third flows as running streams upon the surface; and one-third sinks deep into the earth to form rivers under the earth. In the deepest borings and mine excavations water has been found. There is no doubt that water works its way downward until it comes to that portion of the earth where the internal heat is sufficient to evaporate it. On its way down it performs its work of underground corrosion and disintegration. In this way beds of rock salt are dissolved. As the water becomes heated on its downward journey it often becomes very much changed in composition, on account of the substances which it has dissolved out. The excavation which it effects usually brings about landslips in which enormous masses of earth are carried away.

The rivers of the surface of the earth do much more in a mechanical than in a chemical way. Their action is also more noticeable because it is confined to a smaller area. And yet the action of rivers is as nothing compared with the changes brought about by atmospheric forces. The chief forces in river erosion are the velocity

of the current, and the volume of water. It is not alone the force of the water that works; but it sets in motion small pebbles which rub against larger rocks and by the grinding of surfaces produce a wearing-away on both. Sharp, jagged fragments of rock are worn down to smooth pebbles, these in turn become sand; and felspar becomes mud. A steady flowing river does not cause so much damage as does one that has periods of flood and drying. There are many instances of the wearing away of rocks into deep channels and gorges, such as Au Sable Chasm in New York State; Niagara Falls and River, where the wearing has gone on unevenly; and the cañons of Colorado. The matter which rivers carry down with them is called alluvial matter. The power of a stream depends upon its velocity and volume. If these are suddenly increased rocks and other bodies that have long withstood the ordinary force are instantly swept away. Johnstown, Pennsylvania, in 1889, felt the force of the flood when iron bridges, locomotives, and large masses of all kinds were instantly swept away by the tremendously augmented volume of water. It must not be forgotten that rocks are lighter in water than in air by reason of the buoyancy of water. Rocks average 2½ to 3 times the weight of an equal volume of water. Therefore a rock loses from one-third to two-fifths of its weight in the water. This aids in its movement by the water. A flat thin piece of rock is carried more easily than a compact shaped piece; and rounded pebbles are rolled along. It is estimated that the Mississippi carries down every year 7,500,000,000 cubic feet of solid sediment. The aggregate of the mass borne downwards to the sea by such large rivers as the Mississippi, Amazon, Nile, and Ganges is enormous.

Glaciers do not flow downward as snow falls from an inclined plane. They flow as though they were rivers of ice. One can imagine a thick fluid in motion. That is the motion of a glacier. The whole mass does not move as an iceberg would. There is not the distance of motion recorded at the upper as at the lower end. Its motion is extremely slow. When a strain is produced upon any part of a glacier it is brittle enough to break under it and a great crack, or crevasse, is formed. The motion varies with the mass, the slope, and the temperature. Glaciers in the Alps move from 2 to 50 inches a day in summer and from 1 to 25 in winter. In Alaska the great mass that enters Glacier Bay moves 70 feet a day in summer. The motion and direction of glaciers are to be seen in the scratches which they leave upon the surfaces of rocks and these are the most interesting remains of the Glacial Period in the history of the world. Rocks are ground down, crushed, scratched, polished. and worn by the pressure and motion of the tremendous mass. Great rock masses are carried along by the glacier

in its motion and these are called moraines. When the glacier melts the mass of rock breaks through and is deposited. In this way enormous masses of rock have been left in isolated places and are of entirely different geological structure from those near them. The ice which forms at the bottom of rivers and along the coasts carry rocks and boulders for long distances and drop them on melting. The power of the sea is mainly that of the waves raised by winds. This is always much greater in winter than in summer. A series of observations made on the coast of Scotland show that the wave force is 611 pounds per square foot in summer and 2,086 pounds in winter. The waves dash against high rocky coast lines and undermine the cliffs so that great masses of rock tumble from above into the sea. Very little damage is done by the waves to a sandy coast line. The effects of organic matter such as grass-roots, turf, sea-weeds, are more largely protective than destructive. They serve to bind loose soils together by the massing of their roots. There are however certain destructive effects of a chemical nature which are brought about by the acids formed during vegetable decomposition. These are taken up by the percolating rain water which becomes a greater solvent. The germination of seeds in crevices in rocks and the added accumulation of matter by their growth and decay is an important mechanical agency in the breaking of rocks. The family of plants known as Saxifrage or Rock-breakers takes its name from this habit. The boring of a number of rock-boring shell-fish is an important agency in rock-breaking. The grinding of the soil by earth-worms and the deposit of the soil on the surface is a sort of deep-soil ploughing and involves much greater quantities than might be supposed. There are many reconstructive processes carried on both on land and at sea. The disintegration or breaking down of rocks to form soil and its transportation by water, wind, and frost is the most familiar and perhaps the most important. The talus, or blocks of stone which fall at the bottom of slopes or at the foot of cliffs, piles up a great mass of matter in new places. The volumes of dust, called sand-storms, that are carried by winds in desert lands form dunes or sand-hills. Calcareous deposits are also left by water from springs. The extensive guano deposits are important accumulations. Water charged with carbonate of lime held in solution often falls from the roof of caves in limestone deposits and forms the stalactites, or lime-stone icicles which hang from the roof; and the stalagmites which are built up from below, such as are to be seen in Luray Cave in Virginia. Swamps and bogs are formed from the decay of vegetable matter. The formation of peat bogs, the initial step in the process of coal-making are important reconstructive processes. The Great Dismal Swamp of the south,

30 miles long and 10 wide, is a great mass of peat over 15 feet deep. It is covered by the Swamp Cypress and this prevents evaporation. The bottom of the bog is composed of fire-clay through which the water from the swamp cannot soak. Bog iron ore is often found at the bottom of bogs and swamps.

The alluvial matter brought down by rivers is deposited at bends or curves of the river and at the mouth. It is usually deposited in layers or strata composed of gravel, sand, and mud. When it is deposited along the streams it forms terraces; when carried down to the mouth, deltas are found. The most notable of these are the deltas of the Nile, Ganges, Brahmapootra, and the Mississippi. The delta of the Mississippi is growing out into the Gulf at the rate of one mile in sixteen years.

Some reconstruction is performed by lakes, either through the deposits which are brought into them by tributary streams or those formed by the water of the lake cutting away the shores. In salt lakes there is a larger chemical deposition than in fresh lakes. The chief deposits are carbonate of lime, red iron oxide, gypsum, and salts of magnesium and calcium. Floating ice and glaciers tear down in one locality and carry the material to be deposited in another. This accounts for the very large single rocks and rocking stones so frequently found.

The work of reconstruction is most actively carried on in the sea. The deposits along the shore are known as littoral deposits and consist of mud, gravel, and sand. The shallow water deposits are just beyond the low-water mark. The deep-sea deposits are formed of mud, of coral and volcanic origin, ooze, and clay. The shore deposits are chiefly made up of the alluvial matter brought down by the rivers which empty into the sea. As the wave action is most marked on the shore this matter is ground by the waves and the finer particles washed out as the waves retreat and are deposited in quiet water. The larger, coarser fragments in littoral deposits are found near the shore. The finer matter occurs farther out and is stratified. This matter becomes solidified by several agencies. When the deposit is very thick the weight is sufficient to consolidate the lower layers. There are also many cementing substances carried by the water. Among these are carbonate of iron, carbonate of calcium, and oxide of silicon. These when deposited in the spaces of the fragments bind the particles into firm rock. In the vicinity of volcanoes there is often sufficient heat to consolidate the particles. All the processes above mentioned are the forces that are constantly at work upon the face of the earth bringing about some change. In the processes no matter is destroyed. There is a circulation of the material which tends to modify the face of nature.

Structural Geology is concerned with the materials of which the solid earth is composed. These are spoken of as rocks and minerals. A rock is a mass of the earth's crust which usually, but not always, consists of a mechanical mixture of two or more minerals. Geologists also speak of masses of sand, clay, and loose gravel, as rocks. All are divided into (a) Igneous, (b) Sedimentary, (c) Metamorphic rocks. Igneous rocks are so called because there is every reason to believe that they were originally formed by the agency of fire. They were the first formed and are called primary rocks on that account. As they are not stratified they are often called massive and sometimes eruptive. When they originated deep down in the earth and are exposed by the removal of upper masses they are called plutonic. When they are the result of volcanic upheaval they are called volcanic. If Igneous rocks are classified according to size, shape, and appearance there are (1) the glassy Igneous rocks. This is of the appearance of glass or slag from a furnace. These are sometimes marked by openings caused by escaping steam and are vesicular, scoriaceous, or pumiceous, according to the size and number of the holes. If the holes have been filled up by a later deposit of a mineral the rock is called amygdaloidal. (2) The compact Igneous rocks have a stony appearance due to a number of very small crystals. When these crystals are too small to be seen with a microscope they are called cryptocrystalline, when the crystals can be so seen it is microcrystalline. (3) Porphyritic Igneous rocks are composed of large crystals embedded in a mass of either glossy or compact rock. (4) Granitoid Igneous rocks are of an entire crystalline structure, without any ground mass, and the crystals are of uniform size. When Igneous rocks do not come under any of these groups they are called fragmental, and include volçanic deposits of ashes, bombs, etc.

SOME COMMON METALS AND THEIR ORES

By BAXTER MORTON, M. D.

The term *Metal* is a very familiar one, but if we try to define it exactly, we find it quite difficult to do so. The various substances that we call metals differ considerably in their properties, and it is almost impossible to select any property which is possessed by all the metals and not possessed by any other substances. For this reason we shall not attempt to lay down any rule by means of which we may always distinguish metals from other substances.

IRON ORES

Pyrites
Limonite
Hematite

Magnetite.

Pyrites
Limonite
Specular

QUARTZ AND SILICATES.

1—Asbestus. 2—Feldspar. 3—Quartz Crystal. 4—Small Garnets in rock. 5—Garnet. 6—Opal. 7 Smoky Quartz

But, before beginning our discussion of the various metals that we use most frequently in our every-day lives, we will consider the properties that we are accustomed to find in metals, and which are possessed by all metals in varying degrees. These properties are luster, sonority, hardness, density, tenacity, malleability, ductility, conductivity, and fusibility. With some of these terms you are no doubt familiar, but some of them are probably new to you, and it may be well to explain them all.

By the luster of metals is meant the bright and glistening appearance that they possess, through their power to reflect the light that falls upon them. In some metals, this property is much more noticeable than in others. Iron, in the form of steel, is capable of exhibiting a very high luster, because its hardness makes it possible to give it a high polish, by rubbing it with fine particles of such substances as emery and diamond dust. Tin and silver also possess a marked metallic luster, but they do not take so high a polish as steel. Lead and zinc, on the other hand, are rather dull metals, whose luster is never great.

All the metals that have been mentioned are white or grayish in color, and most of the metals resemble them in that respect; but a few, such as gold and copper, have very different colors. Both the color and the luster of most metals are shown much more perfectly upon surfaces that have not been long exposed to the air. The reason for this is that some of the substances present in the air combine chemically with the particles of metal, on the exposed surface, and form films that cover the surfaces of the metals, so that their real color and luster are hidden. In most cases, these films are formed by the action of the oxygen of the air and are, therefore, called oxides; but some metals, silver for example, are not tarnished rapidly by oxygen, while they are quickly affected by other substances that are occasionally found in the air.

The sonority of metals is that property which, in common language, we call *metallic ring*. The degree in which we find this property present in different metals varies greatly. Lead, zinc, and tin are almost without it, and, when struck, give off a sound that is dull and flat; but most metals have the property in more marked degree and yield a clear, ringing sound when struck.

The common metals, with the exception of mercury, which is liquid at ordinary temperatures, are quite hard,—that is, they resist cutting or scratching. Even lead, which is one of the softest of the common metals, is tolerably hard, while steel is one of the hardest substances known.

The great density of metals, by which is meant their great weight in comparison with the weight of equal volumes of water, is one of

their most striking properties. Density is sometimes called *specific gravity*, and is expressed by a number that shows how many times as heavy as an equal volume of water a quantity of the metal is. Thus, the specific gravity of gold is said to be 19.34, which means that a cubic inch of gold weighs 19.34 times as much as a cubic inch of water.

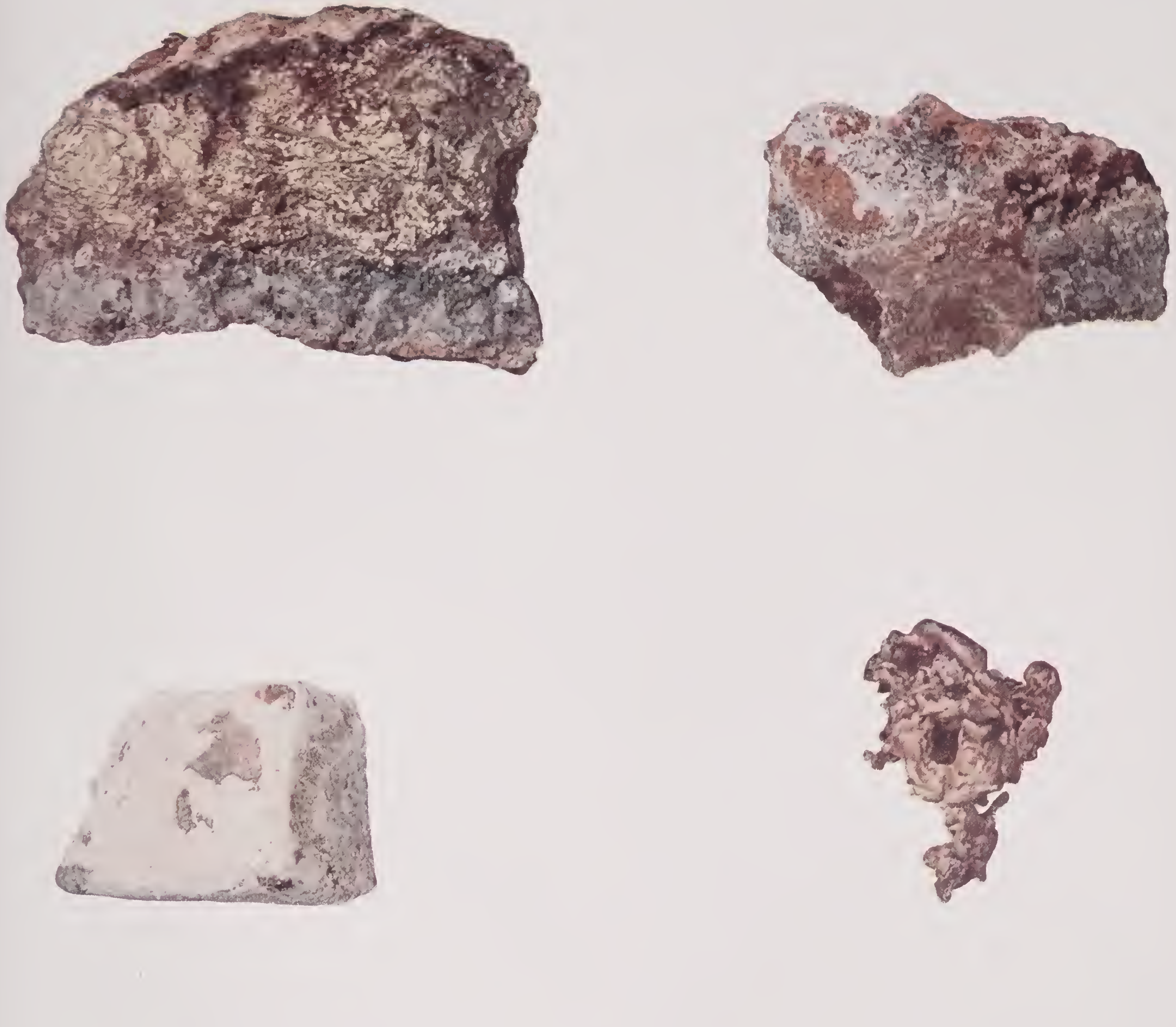
That property of metals which makes some of them useful in the form of chains and wire ropes, namely, the strength with which they resist attempts to pull their particles apart, is known as tenacity. Iron, in the form of steel, has more tenacity than any other common metal and is, consequently, used more than any other metal for purposes in which that property is of importance.

Malleability and ductility are two properties of the metals that are closely related, and a metal possessed of a high degree of malleability, usually has a similar degree of ductility. By the malleability of a metal, is meant its capacity of being hammered out into thin sheets, and to say that a metal is ductile, is to say that it can be drawn out into wire. Gold, silver, and platinum are the most malleable and ductile of the common metals, gold being possessed of both properties in the greatest degree. Gold can be beaten into sheets thinner than the thinnest tissue paper, and drawn into wire so fine that it can scarcely be seen.

From the fact that metals, as a class, allow heat and electricity to pass through them, they are called good conductors, or, in other words, they have "a high degree of conductivity." Silver is the best conductor of heat, and gold, copper, and aluminum follow, in the order in which they are named. As a conductor of electricity, copper is best, and next in rank come gold and zinc.

No doubt you have observed that when some metals, such as lead, tin, and zinc, are heated to a high temperature, they are converted into liquids. The property of changing into a liquid, as a result of heating, is known as *fusibility*, and it is possessed by all metals; but the temperature required to melt some metals is so high, that it can be produced only with great difficulty. The temperature at which each metal melts is always the same, and is known as its *melting* or *fusing point*.

The fusing points of metals that melt easily, such as tin, lead, and zinc, may be determined quite accurately, but we have no way of measuring the temperature at which platinum melts, as well as other metals of difficult fusibility. Mercury is, of course, the most readily fusible of the common metals, for it is liquid at ordinary temperatures. In fact, it was not known, until long after mercury had been discovered, that it could be converted into a solid by cold. For



ORES.

Cholcopyrite
Cerussite coating Galenite
Galenite

Anglesite
Native Copper
Chalcocite

CARBONS.

Anthracite Coal — Bituminous Coal — Graphite

this reason, it was not at first considered a metal, but when it was found that it could be solidified by cold, and that it thus possessed the other properties usually found in metals, it was so classed.

Tin is the most readily fusible of the metals that are solid at ordinary temperatures. Its melting point is 442° F., a temperature that is more than twice as high as the boiling point of water. Lead melts at 617° F., zinc at 773° F., silver at 1,800° F., and gold at 2,000° F. Steel is said to melt at 4,000° F., but this is only a guess at its melting point, for it has never been measured accurately.

When most metals are heated to the melting point, they pass suddenly from the solid to the liquid state, but iron changes very slowly. First, it softens into a pasty condition, and this paste gradually becomes softer and softer, until it reaches the liquid state. While in the pasty condition, two pieces of iron may be made to unite into one piece, if they are laid one on the other and hammered briskly. Uniting pieces of metal in this way is called *welding*.

In some instances, metals can be made to mix by melting them together, and the mixtures of metals produced in this way are known as *alloys*. The properties of alloys are sometimes different from those of the metals that compose them, and consequently alloys are often better suited for certain purposes, than any pure metals. Brass is an alloy of zinc and copper; type metal is composed of lead and antimony; and bronze consists of 95 parts of copper, 4 of tin, and 1 of zinc.

Gold is always used in the form of an alloy with copper or silver, and the proportion of gold in the alloy is expressed by saying it is a certain number of carats fine. Pure gold is 24 carats fine, and in an alloy of gold, each carat represents $\frac{1}{24}$ part; thus 10 carat gold is an alloy containing $\frac{10}{24}$ gold and $\frac{14}{24}$ silver or copper, usually the latter.

You probably know that all metals are obtained from deposits in the earth, by mining. You may not know, however, in what form they are found in the earth. Very few are found in large lumps of pure metal. Some are occasionally found in small particles, mixed with large quantities of other material, usually rock; but most metals are found chemically combined with other substances, and these compounds, containing the metals, are usually mixed with rock. All of the natural substances that contain metals in sufficient quantity and in such form that they can be profitably extracted, are known as *ores*. These ores vary greatly in color, hardness, density, and other properties. The ores of the same metal are frequently so unlike, that only those who have studied them, recognize them.

Let us now turn our attention to some of the most useful metals and consider them separately, beginning with iron, because it is by far the most useful of all.

Iron is the strongest, and at the same time one of the lightest, of metals. It is capable of assuming the forms of cast iron, wrought iron, and steel, each of which has properties that make it useful for a number of special purposes. In the form of cast iron, it is easily fusible and hence adapted to be cast into various shapes. Steel is distinguished by great elasticity, hardness, and strength. It is, therefore, used for making tools, cutlery, etc.

Wrought iron is also extremely strong and tough, but it is inelastic and is soft enough to be bent, twisted, hammered, and rolled into the most varied forms without cracking or breaking. All the forms of iron can be rendered magnetic and, for this reason, it is much used in the manufacture of magnetic and electrical apparatus.

The methods by which iron is extracted from its ores and converted into the three forms that have been mentioned, are fully described in another part of this volume and need not be detailed here. Nothing has been said about the ores of iron, however, and they will now be described.

Iron is very rarely found in the pure state, for the reason that it enters readily into combination with other substances especially with oxygen. Its most important ores may be divided into three classes, first, those containing iron in combination with oxygen, forming oxides; second, those in which it is combined with oxygen and carbon, forming carbonates; third, its compounds with sulphur, or sulphides.

The ores of the first class contain a larger proportion of iron than the others — about seventy per cent. — and the iron obtained from them is usually of excellent quality. The most important ores of this class are known as *Magnetite*, *Red Hematite*, *Specular*, and *Brown Hematite*.

Magnetite is an ore which has the property of attracting iron and steel, or, in other words, it is magnetic, and for this reason it has received its name. The loadstones of ancient times, about which many remarkable stories are told, were no doubt fragments of this ore. Magnetite is usually found in compact, heavy masses of black or dark gray color, and it has considerable luster. Its specific gravity varies somewhat, but is never far from 5. It is found in great quantities in Norway, Sweden, Russia, and, in this country, on the shores of Lake Superior. Magnetite contains a little higher proportion of iron than any of the other ores of its class.

Red Hematite is so called from the Greek word for blood, the name having been bestowed on account of its dark red color. In appearance, it is one of the most striking of the ores of iron. It is often found in rounded masses of brownish red color, having considerable luster, and made up either of layers resembling the thick shell of some large fruit, or of fibers, like petrified wood. These masses

have a specific gravity of 5 and are very hard. Occasionally this ore is found in much softer earthy-looking masses of brighter color, with which clay is sometimes mixed. Red Hematite is found in Great Britain, many parts of Europe, and in the southern part of the United States. Iron Mountain and Pilot Knob, in Missouri, are composed almost entirely of this ore.

Specular Iron Ore has the same chemical composition as Red Hematite, but is found in crystals of steel-gray color and brilliant luster. It is the most lustrous of the iron ores, and from that fact it has received its name, which is derived from the Latin word *speculum*, a mirror. This ore is found in Germany, Russia, Spain, and Nova Scotia.

In *Brown Hematite* we find the same compound of iron and oxygen that is found in Red Hematite and Specular Iron, but it is chemically combined with water. For this reason it is sometimes known as *hydrated* iron ore. Its appearance varies considerably. It is sometimes found in large, rounded masses and sometimes in small grains, called *pea iron ore.*

Other forms of this ore are soft, brown, earthy minerals, called *ochers* and *umbers.* Brown Hematite is abundant in some parts of England and France, and, in the region around Pittsburg, it is the most important iron ore. From the fact that it is sometimes found in marshy places it is also known as *Limonite* or *Bog Ore.*

The important ores of the second class are *Spathic Iron Ore* and *Argillaceous Iron Ore.* The former consists of nearly transparent, shining crystals, which are of the same form as those found in marble. Almost invariably, it contains the metal manganese, and for this reason it is especially adapted for use in the manufacture of certain kinds of steel.

Argillaceous Iron Ore is ore containing a carbonate of iron, of the same kind as that found in Spathic Iron Ore, mixed with clay. It appears in masses of varying size, which are hard and strong in consistency and of a gray, blue, or brown color. It is the most important of the iron ores found in Great Britain.

The only iron sulphide found abundantly in nature is *Iron Pyrites.* It has very little value as an iron ore, but it is of interest from the fact that it is often mistaken by ignorant persons for gold, and is sometimes called "Fool's Gold." It is a heavy mineral, of yellow color and considerable luster, and is often found in coal.

Gold, the next metal to which we will turn our attention, is one that is exceedingly useful for many purposes, but its scarcity makes it too precious for use, in many of the ways in which it would be employed if it were less valuable. It is, as you know, a very heavy

metal, of rich yellow color and brilliant luster. It is the most malleable and ductile of all the metals, and is an excellent conductor of electricity. It is one of the most sonorous of the metals and when struck it yields a clear, ringing sound. It is too soft to withstand much wear and has very little tenacity. The properties of gold that make it especially useful for money and for ornaments are its rich color and its resistance to almost all the agents that tarnish other metals.

In nature, gold is almost always found in the free state, either pure, or mixed with other metals, usually silver or copper. It is practically never found in chemical combinations with other substances, but nearly always it has mixed with it some silver, copper, or lead. The chief natural deposits of gold are of two kinds, namely *Alluvial Gold* and *Gold Quartz*. By Alluvial Gold, is meant gold found in the sands or gravel beds formed by streams, and it is usually in small grains or "dust," thin flakes and small lumps, or "nuggets."

The gold which is found in these beds came originally from deposits of Gold Quartz, a transparent crystalline mineral, which has gold scattered through it in fragments of varying size. Under the influence of the weather, the quartz crumbles and is washed into streams, which carry along the fragments by the force of their currents. As the currents grow weaker near the mouths of the streams, the gold and crumbled quartz lodge at the bottom, forming beds of gold-bearing sand and gravel.

Silver is a metal that we always think of in connection with gold, and in nature it is almost always found with gold. It has a brilliant luster, a bright, white color, a clear, metallic ring, and in its ductility, malleability, and conductivity of heat and electricity, it strongly resembles gold. Silver is much more abundant than gold, however, and consequently is not nearly so precious. Like gold, it is not readily tarnished by exposure to the air and is much used for coin and for ornaments.

When found mixed with gold, silver is usually in the metallic state, but it is not always found in this condition. It is commonly found in combination with sulphur, as a sulphide, or with chlorine, as a chloride. *Silver Sulphide*, or *Silver Glance*, is the commonest form in which silver is found. It is a mineral of dull gray color, of slight luster, and is so soft that it may be cut with a knife. *Silver Chloride*, or *Horn Silver*, is, as its name implies, similar to horn in appearance. It is pearl gray in color and turns dark on exposure to air and light.

Copper is a metal whose chief uses in modern times are as electrical conductors and in alloys with other metals. It is a soft metal,

of rich, reddish color and has considerable luster when polished. It is tolerably malleable and ductile and is the best conductor of electricity that we have. When exposed to the air, it becomes tarnished upon the surface in a short time, through the action of the oxygen of the air, which forms two compounds with it, known as the red and black oxides.

The two richest ores of copper are the oxides, that have just been mentioned. *Copper Pyrites*, or yellow copper ore, is the most abundant of the copper ores, and contains copper, sulphur, and iron. Two carbonates of copper form valuable ores; they are known as *Malachite* or *Green Carbonate of Copper*, and *Azurite* or *Blue Carbonate of Copper.* The former is more prized for ornamental purposes than for the copper it contains.

Tin is now used in the manufacture of many utensils for which copper was formerly employed. It is a soft, white metal, which is malleable and ductile to a considerable degree and does not tarnish readily in air, or when exposed to weak acids, like those of fruits. On account of its softness, tin is not used alone in the manufacture of household utensils. Instead, they are made of thin sheet-iron which is coated with this metal, and known as tin-plate. Tin is rarely found free in nature, but is usually found in the form of an oxide called *Tin-stone*, or *Cassiterite.* This is a heavy brown or black mineral of considerable luster.

Lead is a metal that resembles tin in many respects, but its color is darker, its luster less brilliant, and it tarnishes more readily. It is used in a number of alloys, one of the commonest being *Solder*, which is composed of lead and tin. It is also used largely for water pipes, because, after the formation of a thin film of oxygen on the inner surface of the water pipes, no further change in them takes place.

The only important ores of lead are the sulphide, which is known as *Galena*, and the carbonate, or *White Lead.* The former, which is the more abundantly found, is a mineral that looks much like pure lead. It is, however, crystalline in form and harder than the pure lead. *Lead Carbonate* is usually found mixed with galena, or in streaks running through it. When pure, it is white and crystalline in form, but it is usually dark, from the presence of impurities.

The most abundant of all the metals is one which has come into use only within comparatively recent years, namely, *Aluminium.* This is by far the lightest of the common metals, having a specific gravity of only 2.5. It is a white metal, about as hard as zinc, and its fusing point is slightly lower than that of silver. It has a brilliant luster, closely resembling that of silver, and is not readily tarnished, being superior to silver in that respect. When struck, it yields a remarka-

bly clear, ringing sound. The strength of aluminium is great, in comparison with its weight, and this fact, together with its resistance to tarnishing agents, has caused it to be used in many places in which steel was formerly employed.

The ores of aluminium are a mineral known as *Cryolite* and *Common Clay*. As clay is extremely abundant, you might expect aluminium to be one of the cheapest of metals, but this is not true, for it is very difficult to extract it from either clay or cryolite, and none of the processes of extraction can be carried on cheaply.

ROCKS AND MINERALS

Conglomerate or Pudding Stone

You must often have seen rocks made of small stones of different colors and sizes. Sometimes these rocks are very small but they often become large masses. You may frequently see an enormous mass of such rock standing by itself. It consists, as has been said, of an immense number of small stones of different sizes and of a variety of colors, all fastened together by a sort of cement. The scientific name for rock of this kind is *conglomerate*, but the common name is *pudding stone*. It has received the last name because it is thought to resemble a pudding filled with plums. There are two kinds of conglomerate, one, very common, in which the little stones are round and smooth, and another, not so common, in which the small stones are sharp. The latter sort is sometimes called breccia, to distinguish it from the former, which is the true pudding stone.

The fact that the stones are round in the pudding stone may tell you something about its origin. These round stones are really pebbles, worn smooth and round by being rubbed against one another through the action of the waves, on a beach, or of the running water of brooks and streams. These have become massed together and cemented by the clay in which they are imbedded and the mass converted, by great pressure through long years, into the rock that you have seen. This sort of rock is, therefore, one of the water-formed rocks, like some others of which you will learn later. It is hard to tell how many miles each of the rounded stones, that now lie side by side in a piece of pudding stone, may have been carried by the action of the water. Wherever you see a round smooth rock or pebble you will be safe in supposing that it was so rounded and made smooth by

the action of water. You remember how in « Evangeline » Longfellow describes the sound on the beach: —

> « Rattle loud on the beach in their noisy attrition
> The pebbles drawn down as the great waves retreat.»

Perhaps you have heard the sound yourself, when lying on the beach, as the waves of the incoming tide break along the pebbly shore and, retreating, carry the pebbles down with them. This wearing away of the rough edges and rounding of the sharp corners of the pebbles, by coming in contact with their fellows, is much like what happens to us when we go out into the world amongst our fellow-men, and have our natures shaped and smoothed down so that we become more courteous and agreeable. That is called by some people « having the sharp corners worn off by brushing up against the world.»

If you observe even the commonest rocks and stones you will find that the poet knew the truth in nature when he wrote of « Sermons in stones, books in the running brooks and good in everything.»

Sandstone

Rocks are broken into fragments too small to form pebbles; sand is formed instead. This may be a new thought to you, but such is the case. A grain of sand is only a very small pebble. You will find sand of many colors; but the best sort is the pure white sand that the children love to play in in summer time. You may recognize that kind of sand as fine grains of quartz, a beautiful and very hard white stone which will be described after a while.

If you take a piece of sandstone and separate a few of the small particles of which it is composed you will see that they are really grains of sand of different colors, or it may be, all of the same color. Now, if you examine each of these grains of sand with a magnifying glass, you will see that each is worn and rounded, and looks under the glass just like a small pebble.

That is just what each grain of sand is, and the sandstone is formed in much the same way as pudding stone, by pressure and becoming hardened in the sun. You will see also that sandstone is formed in layers. This is because the sand brought down by rivers forms in layers, and these afterward harden. Shakespeare speaks in the « Merchant of Venice » of men « whose hearts are all as false as stairs of sand.» When sand is brought down by swift-running streams it often forms stairs of sand at the mouths of the streams. You

would know how false they were if you tried to walk upon them, though they look as solid as rock.

Sometimes these layers of sand are exposed at low tide and a bird or an animal walks over the wet sand and leaves the print of its feet in it; then the sun bakes it and it becomes hard, and new matter covers it over, so that when layers of sandstone are split open you may often see in them footprints of a variety of forms. And that, no doubt, is what Longfellow meant when he spoke of the "foot-prints in the sands of Time."

We use sandstone chiefly for building purposes; so it is often called *building-stone.* Some kinds of sandstone are very hard and last a long time while others crumble away very easily under the combined action of frost and the weather. The red color you sometimes see in sandstone is caused by iron which has given its color to the sand of which the stone is composed. Grindstones are made of the finer sorts of sandstone.

Clay

We are all familiar with this substance. We find it on the river banks, in the fields, and, indeed, it is so common that we pay little attention to it. Clay is formed by the crumbling of a certain class of rocks called *feldspars.* When these rocks are exposed to the action of the weather they crumble slowly at the surface and the fragments become chemically combined with a certain amount of water, forming clay. Pure clay is white and is used in the manufacture of china and porcelain, which is described in another part of this volume. The clay that we usually see contains impurities, and like sandstone it is of many colors. Most of these colors, especially those of red clay, yellow clay, and blue clay, are due to iron which is present in the clay. An important use of clay which contains iron is to make bricks which we use in buildings. The clay is made soft and pressed in molds, the size of a brick, and set up in the sun to dry for a time. They are then exposed to the action of intense heat, and when they have become hard enough, they are usually of a dull red color. The clay of which the bricks are made, may be blue or yellow when it is molded into bricks, but, under the influence of heat, it generally becomes red, because the compound of iron which gives the clay its color takes up oxygen and consequently changes color.

Many varieties of clay contain substances which will melt when heated to very high temperatures, but there are some kinds which are entirely free from such substances. The pure white clay, *Kaolin,* which is used for making porcelain, is of this kind, and there are

some coarser kinds of the brick used for lining fireplaces and known as fire-brick.

Some sorts of clay go by the name of ocher and are used to make paints of that name, as yellow-ocher and red-ocher. The fine particles of clay, suspended in water, make it muddy, and we see this especially in the freshets in the spring of the year.

Slate

If you scratch a piece of slate, so as to get some of the dust, you will find that instead of getting grains of sand you get a fine powder. Now, if you stir this in a glass of water you will see that it becomes muddy and that it takes a long time to settle. If you have enough dust you will have no difficulty in proving that it is really clay. And so we learn, that just as sand in layers hardens into sandstone, under the action of heat and pressure, so clay hardens into slate. There are, of course, many kinds of slate, just as there are many different colored clays. At times you will also see markings of the same sort as are found in sandstone, and they are made in the same way.

Slate is used for many useful purposes. In thin, smooth sheets it forms slates to write upon, and in slender round pieces it forms slate pencils. Many of the fireplaces and mantels in our houses, that are made to look like marble, are really slate. Our school blackboards are also often of slate, and some of the houses and churches have slate roofs, but slate is not now used so much for that purpose as formerly.

Limestone

There are a great many rocks that you should recognize at once, when you see them. They are rocks that everyone knows, such as sandstone, slate, granite, etc. Others, like limestone, vary so much in color and general appearance, that these properties are no guide to help us to know them. There are, however, some simple means by which we can easily recognize them. Among these means is the hardness, which may be tested by means of a knife point or, better still, a file. If you are in doubt whether a whitish glistening rock is limestone or quartz, all you need do to determine which it is, is to test its hardness with knife or file. If you can scratch it, it is probably limestone, and it is certainly not quartz, for your file will have no effect whatever on quartz, as it is harder than the file.

Limestone is of many colors, but it is generally bluish gray, or white. It occurs in many different forms, for limestone, marble, and chalk all have the same composition, namely calcium carbonate. It

may seem strange to you, that three substances having different properties should have the same chemical composition, but this is often the case in chemistry, and is one of the most remarkable facts of that interesting science. The chalk that was mentioned above, is not the kind used at school in writing on the blackboard. That is not real chalk, but plaster of Paris. The real chalk is the kind of which the "white chalk cliffs of Dover" are composed. It was formerly used to write with, but is not so clean as the crayons we now use.

Another test by which you can easily tell limestone from other rocks is applied by pouring a diluted acid on the rock supposed to be limestone. If it is limestone it will at once send off a gas with much boiling. If you have access to a chemical laboratory, weak hydrochloric, nitric, or sulphuric acid may be used. If you have not, pour some vinegar on the rock, for vinegar is diluted acetic acid. The gas that comes off is carbonic acid gas, the properties of which have already been described to you. The substance left behind contains hydrogen, oxygen, and water and is known as calcium hydrate or slated lime.

A similar change is produced when limestone is heated in great cone-shaped ovens called lime-kilns. The heat drives off the gas and leaves the white substance that we call quicklime. Quicklime contains calcium and oxygen, but no hydrogen. We make mortar out of quicklime, by mixing water and sand and hair with it. The water combines with the quicklime and forms slack lime, and the slack lime combines with the carbonic acid gas in the air to form calcium carbonic. This change takes place slowly and when it is complete the mortar has "set" or become hard.

There is always a great deal of heat given off when water is added to the quicklime. The heat is great enough to burn the clothing and hands of the workmen, so they are very careful. It may also set fire to some substances. This sometimes happens when vessels carrying lime spring a leak at sea. The vessels take fire and the only thing that can be done is to batten down the hatches to keep the air from getting to the flames and then to make for the nearest land. It is not often that the vessel can be saved.

Gypsum

This, too, is a sort of lime. Limestone is called carbonate of lime, because there is carbon in it. Gypsum is called sulphate of lime, because it has sulphur in it. It is usually white in color and is very soft. You have only to put a drop of weak acid on it to tell that it

is not limestone, for it will not give off any gas even with the strongest acid. When heated, it will give off water instead of gas. It is interesting to take a test-tube and heat a small piece of gypsum in it over a spirit lamp and after a little while pour a few drops of water out of the tube. It seems hard to believe that a dry, hard rock can be made to give off water. Yet this is true of gypsum, and when the water is driven off the gypsum changes to plaster of Paris. Plaster of Paris is so called because it was first made near Paris, in France. It usually comes to us in a fine powder. When water is added to it it quickly "sets," or forms a hard mass, and so is useful for making molds and fastening glass to brass. It is also used to put on the finishing coat of the walls of our houses, as it is whiter and smoother than the plaster with which the walls are covered and gives the walls a nicer finish.

Sometimes gypsum occurs in the form of crystals of a beautiful transparent nature, and it then has a luster of rainbow-like color. This variety of gypsum is called *selenite*, from a Greek word *selene* meaning the moon. It does not look unlike mica, but you can easily tell the difference, for you can scratch selenite with the finger nail, and it does not break off in layers as easily or as smoothly as the mica does. Selenite is also called alabaster, and is much used for making ornaments, such as clocks, vases, etc.

Mica

Everyone must know mica, as it is so commonly used. It occurs in lumps, which may easily be split into thin layers. These layers are transparent as glass and can be used where glass could not. It will bend easily, and will fly back into place again when the strain on it is removed. That may be noted also as another difference between selenite and mica. The selenite will bend, but will not spring back into place. There are two sorts of mica, the white, or colorless variety, which is called muscevite, and the black mica. Heat has no effect on it, so we find it used in stoves and latrobes, where it answers all the purpose of glass and allows the bright, cheerful fire to be seen, yet does not break with the heat. You will often see it glistening in little particles in other rocks, even in sandstones and especially in granite. Sometimes these little particles are of the white kind and sometimes of the black. Whenever you see little glistening pieces in rock, just pick one out with a knife point and try to split it into thin layers. If it splits readily you may be quite sure that it is mica.

Granite

You must have often seen this rock, whether you live in the city, or in the country. It is one of our chief building stones and is used on account of its strength as well as its beauty. Two kinds are gray granite and red granite. You may often see both kinds used as pillars in buildings, either in the rough or most beautifully polished. Granite is also used very largely for monuments in cemeteries and parks. It is one of the common rocks and you can hardly take a walk along the beach or through the fields, without seeing it, either in large masses or in small lumps.

Take a piece and examine it carefully and see if you cannot easily distinguish three different sorts of particles of rock in it. Granite always contains quartz, feldspar, and mica. It is very easy to identify the mica. Feldspar has a most peculiar luster, almost like a piece of taffeta or shot-silk. Its luster also resembles that of the opal, which you have seen used in rings. Sometimes the feldspar is gray, then we say the granite is gray, or the feldspar may be red, then the granite is red, because mica and quartz usually have no color. Granite is a very durable rock, but it will crumble easily under heat, especially the red granite. When a building takes fire the red granite will crumble away quickly. If granite is exposed to the weather long enough it will crumble, or, as geologists say "weather," but the process is exceedingly slow. When granite breaks up, the little particles of which it is composed fall apart and form sand, the little white quartz grains making white sand and the mica forming the little glistening particles you often see in sand.

Gray granite is much harder than the red sort and lasts very much longer, but it is not so ornamental. Both kinds are polished by a machine that resembles a large hand with cloths on it. Emery powder and water are used on the rubbers that move backward and forward over the stone.

Quartz

No other mineral or rock is found in so many colors and in forms so varied as is quartz. If you are making a collection of minerals, and you have a hundred different-looking specimens in your cabinet, it is quite safe to say that at least fifty of them are quartz in one form or other. It is found in crystals and in masses. The crystals are always six-sided and have a six-sided pyramid at one end. It is very hard, so hard that your knife will have no effect upon it; and with a piece of quartz you can easily scratch glass. If you strike

it with a piece of steel, it will give off a spark. It is so hard, that it will not melt and it does not dissolve in acids; but with very strong, boiling acid it often forms a sort of gelatinous mass.

Many varieties of quartz are named from their colors. The colorless, glass-like crystals are called rock-crystals, and are very beautiful. The milky-white variety is called milk-quartz. The pink quartz is called rose-quartz; and the yellowish or brownish kind, when smoky, goes by the name of cairngorm. When quartz is purple, it is called amethyst and is much used in jewelry. Quartz is also blue, green, and gray. The cat's-eye is quartz, in which fibers of asbestos are mingled, so as to give the well-known peculiar effect. So you see that some of the precious stones are forms of quartz.

Besides the forms mentioned, there are many other names for the different forms and colors of quartz, such as chalcedony, agate, onyx, sardonyx, carnelian, heliotrope, flint, and jasper. Some of these are very beautiful, especially when crystallized, and it is often a great surprise to break a rough-looking stone and find in the inside a beautiful cluster of crystals, where you would never in the least expect it. So, you should never judge of the value or beauty of a stone from the outside, any more than you should judge of a person's character or education or true worth from his appearance; for appearances are often very deceptive.

Flint, a form of quartz already mentioned, was once very useful to man. Before he was civilized enough to utilize metals he used to make his arrowheads, spear-heads, and axes, out of flint, and flint implements are found among the relics left by the people who lived in the Old World before it was occupied by men who kept records of their doings. In the New World the Indian used flint weapons until the discovery by Columbus, and it is not at all unusual to find these implements in the ground and about the lakes. It is one of the mysteries in the study of Indian life, to tell how he chipped flint so regularly and beautifully, since it is the hardest work he knew of. We often wonder what he did it with.

For a long time flint was, as you know, the best means of lighting fires. By striking it with a piece of steel, a spark is produced which must be caught on some material that burns easily. The old muskets and rifles were called flint-locks, because the spark which lighted the powder was made by a piece of flint, which flashed the fire on the powder. All these things seem very awkward and absurd to us who have so many conveniences, but we must remember, in our pride, that our descendants are going to achieve many things that would seem wonderful to us.

Besides its value as precious stones, quartz is useful in glass-

making and in porcelain manufacture. Sand paper is made from finely powdered quartz glued to stiff paper.

Very often gold is found in quartz. The quartz is then called gold-bearing quartz and must be crushed by powerful machines, so as to separate the gold from the gangue, as the quartz is then called. But you must not mistake any yellow mineral you find in quartz for gold, for you are very lucky if you have learned that "All that glitters is not gold."

Asbestos

This is a variety of the mineral called hornblende. The easiest way to distinguish hornblende from other minerals is to break it. You will then be surprised to see that it breaks evenly, and always at an angle of about $124\frac{1}{2}°$. It varies so much in color and in composition, that it is almost impossible to describe it. The best way to learn to recognize it is to get someone who knows it to show it to you. After having seen it, you will be able to recognize it whenever you see it. Asbestos is a very strange rock. Indeed, you will hardly be inclined to call it a rock from its appearance. You can separate it into fine fibers which will bend like thread. These fibers can be woven just like strands of cotton or flax. The strangest thing about the fibers of asbestos is that they cannot be made to burn. If a piece of asbestos becomes soiled you can clean it by throwing it in the fire, where all the dirt will be burned off and the asbestos be left quite white and clean. We take advantage of the fact that it will not burn and use it to make lamp-wicks, which suck up the oil, but do not burn as the ordinary wicks do. Some cotton is mixed with the asbestos fiber to make it easier to weave, so the wick does not last forever. Firemen's clothing is made of it, too, as are also building materials, and sheets of varying thickness, for packing steam-joints and pistons. You can always see a sample of it in a prepared form in an engine-room. Asbestos is also used in making a cement for protecting heated surfaces and floors and for several other fire-proofing purposes.

A mine of asbestos to be of any value, must furnish long-fibered mineral. The best comes from Italy and Canada.

Hornblende furnishes a few other very strange forms, such as mountain-cork, which is light and spongy, and mountain leather, which is tough and in some respects resembles leather.

There is a form of the mineral serpentine which looks like asbestos and is popularly so-called; but its real name is chrysolite.

When blue quartz is variegated with fibers of asbestos running through it, we call it tiger's-eye.

Sulphur

This mineral is of such common use, that we all know what it looks like. We know it in two forms, the roll sulphur and the flowers of sulphur. It is found in nature in the neighborhood of both active and extinct volcanoes. Most of the sulphur of commerce comes from Italy, being found upon the slopes of the volcanoes, Ætna and Vesuvius. When found, it has ashes, lava, and other volcanic products mixed with it. It is melted and the foreign matter separated from it by skimming and settling. The melted sulphur is poured into round molds, in which it cools and forms roll sulphur. It is sometimes called brimstone, a word which has the same meaning as burn stone, that is, the stone that burns. Its flame is a pale bluish color and when it burns it gives off a gas which is very offensive and chokes us if we breathe it. This gas is used to fumigate rooms where some contagious disease has been, for it is powerful enough to kill the germs of the disease. The gas is also used to bleach straw, especially the finer kinds, out of which the better sorts of straw hats are made.

Instead of being cast into molds, the melted sulphur is often heated until it boils and forms a vapor or gas. This gas is allowed to pass into chambers where it condenses and falls to the floor in a very fine powder. In this form it is called flowers of sulphur. But it seems from its fineness that we ought to spell it "flour" of sulphur.

When sulphur is heated it forms a sort of gum which can for a little while be drawn out into long threads, but when it cools it gets very hard again. On account of this property sulphur is often used for taking impressions of medals, coins, etc. It is also used in making matches, but its use in this way is not so great as formerly, for the burning sulphur is disagreeable, and better matches can be made without it. The great use of sulphur is in the manufacture of gunpowder, which is described in another part of this volume. It is also largely used in vulcanizing rubber, and in medicine great quantities are used in making sulphuric acid, which is important, because it enters into the manufacture of so many things that contribute to our comfort.

The Marbles

Of the many beautiful varieties of marble there must be some that are familiar to you, for marble is almost invariably the stone from which are formed the white monuments that dot the green turf of the cemetery and stand like sentinels guarding the graves of

departed friends. Some of the darker varieties of marble are frequently used in the construction of mantels for our houses, and sometimes marble is used to form the walls of buildings, especially public buildings, such as court houses and state houses, or capitols. Marble may be the material that forms the walls of the capitol of your own state.

Marble is the name given to the kinds of limestone which are capable of receiving a high polish. The word indicates something sparkling and shining, and fitly describes the material of the rock, which is quite solid and is composed of a great number of small grains or crystals. This indicates the action of heat in the formation of the marble and a change from the natural condition. A piece of white marble looks like white sugar. For this reason it is sometimes called granulated rock, as though made up of hardened sand. Its capacity for taking a bright polish fits it for many useful purposes. In the natural state, marble is the most beautiful of the rocks and when cut into graceful forms and brightly polished, it has no equal for beauty among the minerals of the world.

There are many kinds of marble, which differ in color and in structure. Some are pure white, some show several colors mixed together, and some are black. The many kinds may be divided into four classes.

To the first class belong simple or *single-colored* marbles. The best known are the plain white kinds used for making statues and for the better kind of tombstones. The white marbles are composed of pure carbonate of lime; the coloring matters in the other marbles are impurities. In this country white marble is obtained at Rutland, Vt. The best marbles for statues, however, are found in Europe. Three pure white marbles found in Europe, have long been famed for their beauty. The Pentelic marble, from Mount Pentelicus, in Greece, is one. Another is the Parian marble, from the Island of Paros. The third is the Carrara marble, which takes its name from the place in Italy where it is found. These marbles have been used in most of the famous statuary of the world. Carrara marble is of the kind called *sugar-loaf* marble because its crystals resemble grains of sugar. These kinds of marble have no color and no vein or shades to mar their perfect whiteness.

Another single-colored marble is the black variety found at Shoreham, Vt., and at Glen's Falls, N. Y. This is as black as the other is white. It is much used in making mantels and vases. It is also employed in making small figures and ornaments.

The dense brown marble that, when polished, resembles rosewood, also belongs to this class. Another is the marble of saffron tint,

which is known in this country as California marble, and in Europe as the *yellow antique*.

To the second class belong the *variegated* kinds of marble. They are stones that are spotted, shaded, and streaked with several colors. The Tennessee marbles are the types of the class in this country. None are more highly prized than the Siena marble of rich brown, gray, and red shades and markings. It is extensively used for mantels and table tops, and for the ceilings and walls of public buildings. The dove colored Lisbon, the black Genoese, with golden colored and white veins, both found in the Rocky Mountains, are other examples of this class. There are many other marbles in this class, but those that have been mentioned are the most noted varieties.

These stones are of great beauty and the markings, even upon pieces from the same block, show much contrast and variety. A staircase finished with Tennessee marble is a source of increasing wonder as the veins and shades of color in the stone are studied.

To class three belong the *brecciated* marbles. The name brecciated was given to these stones in Italy and means angular. This kind of marble has large and showy streaks of color in lines forming angles. The groundwork may be white or of some other color, while the brecciate lines are black, gray, and red. It is supposed that these markings were caused by the presence of angular pieces of mineral in the original limestone mass. The forms of these minerals are retained in the marble, while their substance long ago became part of the rock.

The principal variety of this class is called *brocade* marble. It has a light body clouded and veined with colors to suggest brocade fabrics. The original brocade was silk, into which were sewn figures in gold or silver thread. Later it was white stuff, upon which were woven figures in red and other colors. The prevailing color of the *brocade* marble is yellow, and this is streaked with white, gray, and red, forming some very striking, as well as very beautiful combinations. The chief quarry in the United States is in Maryland, a few miles from Washington, D. C. The stone from this quarry was used in the decoration of the interior of the Capitol at Washington. Other deposits of this marble are at Knoxville, Tenn., and in Vermont, near Lake Champlain.

Columns or pillars of *brecciated* marble are of wonderful beauty. This is especially the case with the Vermont stone, which has a rich gray groundwork with black markings.

To class four belong the *lumachella* or shell marbles. Lumachella is the Italian name of a small snail, very common in that country. This name was given to the marble because it contains many fossil

shells, resembling those of the Italian snail. These shells in the stone give it a peculiar shining appearance, which in England suggested the name *fire-marble.* These marbles take less polish than the other kinds, and their colors are dark. They are used chiefly in building fire-places. The reflection of the fire from the marble at night gives it a ruddy glow, in which the marble itself seems to be on fire. The best specimens in the United States are found near Hudson, N. Y.

One of the most interesting marbles of this class is that found in the Isle of Man. This variety of marble contains fossil lilies, which can be cut so as to show their original forms. They are called *stone lilies.* They are supposed to have been plants originally and to have been a part of the mass which formed the stone. When the marble is cut so as to divide the lilies, they appear in spiral form on the face of the slab. They are of the calla species and seem to be petrified in the marble. The stems show as round spots, the center being of a different color from the outside, and the figure in the marble has received the name of *wheel stone.* A similar formation, in which it is supposed that fossil reeds take the place of the lilies, is the *birdseye* marble of New England. In this there is a number of white spots in a gray field.

Serpentine is a stone which admits of high polish, and is much used for the same purposes as marble. It is, however, not marble. It contains about equal parts of sand and magnesia and twelve parts of water in one hundred. It has a soft texture, is of a waxy appearance and is found in many shades of green. True serpentine has many reddish spots which give to it the mottled appearance of a serpent's skin, whence the name.

Alabaster, a stone of purest white, is also similar to marble, but is composed of lime and sulphur and not lime and carbon. It is not true marble.

A showy kind of marble is formed by the waters from limestone rocks running down in the crevices and caves of the rocks below. These waters carry lime in solution, which is left behind when the water falls upon a projecting stone. In time, great beds of marble are formed in this way. Marble of this kind is of various colors and in general resembles serpentine, except that it is true marble. It has received the name *cave marble* from the manner of its formation. It is found near the city of Mexico and in the mountains of New Mexico.

In order to understand the peculiar streakings, markings, and colors of marble it is necessary to learn something of how these beautiful rocks were formed. They are of the same composition as the limestones, yet they differ greatly from them.

At various times when the rocks of the earth's crust were being formed, the limestones were slowly developed at the bottom of the sea. Many mollusks, second cousins to the oyster and clam of the present day, lived in its waters. As they died their shells were spread in thick layers on the floor of the ocean. Sometimes the lime coat of the coral insect was added to the mass. After a long period the shells were covered over with sand and clay in some disturbance of the water, and thus the foundation of the limestone was laid. In time the mollusk shells changed under the influence of heat and pressure and were hardened into stone.

The formation of other rocks above, added to the pressure, and this with the heat from the internal fires of the earth, operated to bring another change. The limestone was partly melted and afterward in cooling passed into the granulated form, in which we find it to-day.

With the mollusk shells, other things were sometimes mingled. There would be deposits of iron or other metals. Sand, mica, clay, and other minerals, were added to the heap, and all these had their effect, when the rock underwent its last change and came out granulated rock. For instance the color of black marble is due to the presence of vegetable matter in the rock which stained it black. Landscape marble, or Gotham stone, as it is called, in which the face of the marble presents markings resembling a picture of old ruins, was so colored by water carrying into the stone, before it was hardened, a black metallic substance called the oxide of manganese. The brown and red colors of marble are traceable to iron, as are the yellow tints. The streaked and clouded appearance of much of the American marble is due to sand or mica in its composition. There are black veins of mica in the rose-colored marble of Danville, N. J., and a quarry near Chicago was abandoned a few years ago because the marble was stained with petroleum or rock oil.

The quarrying of marble is a simple operation. Steam or hand drills are used for boring into the stone, along the lines on which the quarry man wishes to divide the rock. The blocks are loosened by steel wedges, driven into the holes made by the drills. They are then lifted out of the pit by means of a derrick, and cut into the required shapes and sizes in the mills connected with the quarry.

As marble is a soft stone, it is cut into slabs and partly polished at the same time. The block from the quarry is sawed with smooth saws, fed by sharp sand and water. The rate of progress of the saw through the block of marble is only about an inch an hour; but several saws are placed in a frame and at one cutting twelve or more slabs are made. Twenty or more frames of saws may be in operation at the same time. As the saws work their tedious way through the

block of marble, the slabs cut off are made nearly smooth, so that comparatively little work is required to finish the polishing. The polishing of marble is done largely by machinery, though much of the finer work is done by hand. It is accomplished by rubbing various substances — iron, wood, or another piece of marble — over the surface to be polished, upon which is smeared marble dust wet in water or oil.

Many tons of marble, mostly the chips and waste product of the quarries, are ground fine like flour, and the marble dust, as it is called, is used in the production of carbonic acid gas for charging the water sold at soda fountains. The consumption in this way is about 200,000 barrels of the dust every year.

Coal and Coal Mining

The heavy black *mineral called coal*, which we burn in our stoves and furnaces, and use to heat the boilers of our engines, was formed from trees and plants of various sorts. Most of the coal was formed thousands of years ago at a time when the atmosphere that envelops the earth contained a much larger proportion of carbonic acid gas than it does now, and the climate of all regions of the earth was much warmer than it now is. This period was known as the *carboniferous age*, that is, the coal-mining age, and its atmospheric conditions favored the growth of plants, so that the earth was covered with great forests, of trees, giant ferns, and other plants, many of which are no longer found on the earth. In the warm, moist, and carbon-laden atmosphere of that period the growth of all kinds of plants was rapid and luxuriant, and as fast as old trees fell and partially decayed, others grew up in their places. In this way, thick layers of vegetable matter were formed over the soil in which the plants grew. In many places, where these beds were formed, the surface of the earth became depressed and the water of the sea flowed over the beds of vegetable matter.

Sediment of various kinds was deposited over the vegetable matter, and in the course of centuries the sediment was transformed into rock.

After the formation of the covering of sediment, the decay of the vegetable matter was checked, but a slow change of another kind was brought about by the pressure of the sedimentary deposits and the heat to which the plant remains were subjected. The hydrogen and oxygen which constituted the greater part of the plant substance was driven off and the carbon left behind. This change took place very gradually, through periods so long that we can only guess at

their duration, but we know that many beds of coal were formed from layers of vegetable matter that were covered up many thousand years ago.

The coal first formed and submitted longest to pressure is known as hard coal, or anthracite. It is pure black, or has a bluish metallic luster. Its specific gravity is 1.46; which is about the same as that of hard wood. Anthracite contains from 90 to 94 per cent. of carbon, the remainder being composed of hydrogen, oxygen, and ash.

Hard coal may be called the ideal fuel and is especially adapted to domestic heating purposes. It burns without smoke and produces great heat. There is no soot deposit upon the walls of chimneys, and in good stoves or furnaces the small amount of gas given off by it is consumed. Anthracite is the least abundant of all the varieties of coal and is much more costly than the other varieties. For this reason it is not much used in manufacturing.

The coal formed later is very different in composition and is called bituminous or soft coal. Its name is derived from the fact that it contains a soft substance called bitumen, which oozes out of the coal when heat is applied to it. Soft coal contains from 75 to 85 per cent. of carbon, some traces of sulphur, and a larger percentage of oxygen and hydrogen than anthracite. When soft coal is heated in a closed vessel or retort, the hydrogen and oxygen, in combination with some carbon, are driven off.

This coal is black, and upon smooth surfaces it is glossy. It lacks the bluish luster sometimes seen in hard coal and is much softer and more easily broken. When handled it blackens the hands more than hard coal does. In this kind of coal are frequently seen the outlines of leaves and stems of plants that enter into its formation. Occasionally, trunks of trees with roots extending down into the clay below the bed of coal have been found.

Soft coal has a specific gravity of 1.27. It burns with a yellow flame which is larger than the flame from hard coal, but it does not emit so high a degree of heat. Combustion, generally imperfect, gives rise to offensive gases and to black smoke that concentrates in the air and falls to the ground as soot, which blackens buildings, and, in winter, noticeably discolors the snow. Bituminous coal is, on account of its cheapness, the manufacturer's fuel. It also feeds the furnaces of the locomotive and the ocean steamship. From it is made the gas that lights the cities, and the inferior grades of it baked in ovens, to drive off the impurities, yield coke — a valuable fuel that is chiefly used in smelting iron ore.

Another kind of coal, called *lignite*, is still less developed than soft coal. It is of later formation, and of less value as fuel. Lignite in-

cludes all varieties of coal intermediate between peat, which will be described next, and bituminous coal. It is of a yellow or brown color, shading into dull black.

The formation of lignite has been observed in the timbers of some old mines in Europe. In some of these mines wooden pillars have been supporting the rocks above for four hundred years or longer, and in that time the pressure of the rocks and other influences acting upon the wood of the pillars have caused it to become transformed into a brown substance resembling lignite. This fact tends to confirm the theory of coal formation stated at the beginning of this article. The proportion of carbon in lignite is never above 70 per cent., and the ash indicates the presence of considerable earthy matter. It is chiefly used in those forms of manufacture where a hot fire is not required. In Europe it is used, to some extent, in heating the houses of the poorer classes.

Peat is regarded as the latest of the coal formations. In it the change in the vegetable matter has not extended beyond merely covering it, and subjecting it to slight pressure.

Peat is formed in marshy soils where there is a considerable growth of plants that are constantly undergoing partial decay and becoming covered by water. It consists of the roots and stems of the plants matted together and mingled with some earthy material. When freshly dug out of the bog or marsh in which it was formed there is always a quantity of water in it, the amount being greatest in the peat found nearest the surface and least in that at the bottom of the bed, where the peat is not very different in appearance from lignite.

Peat is used for fuel where wood is scarce and coal is high in price. Recent experiments in saturating peat with petroleum, have shown that in this way a form of fuel may be produced for which considerable value is claimed. Its manufacture is confined to Southern Russia, where peat is plentiful and petroleum is cheap.

In the great length of time that has elapsed since the carboniferous age, many of the beds of rock composing the earth's crust have been formed and some of the beds of coal formed at that time have been covered by layers of rock thousands of feet in thickness. Over many of the coal beds thus formed, however, the conditions for rock formation did not exist long and the coal was not covered so deeply. In some regions the conditions have become so changed, that rocks formed over the coal beds have been worn almost entirely away and the coal exposed in places, on the surface.

The coal deposits of the United States exceed in area those of any other country. The chief deposits of hard coal are in Eastern Penn-

sylvania, but coals similar in quality are found in Massachusetts, Rhode Island, Virginia, North Carolina, Arkansas, and Texas. Soft coal occurs in considerable quantity in Ohio, Pennsylvania, Maryland, Virginia, West Virginia, Kentucky, Tennessee, Georgia, Alabama, Arkansas, Missouri, Indiana, Illinois, Iowa, Michigan, Kansas, Nebraska, Indian Territory, and Texas. Lignite is found in almost every state and territory west of the Mississippi, as well as in some of the Central and Southern States.

The output of coal in the United States is about 225,000,000 tons per annum, and, with the exception of about 10,000,000 tons which are exported every year, it is all used in this country as fuel, or for the manufacture of illuminating gas.

The Mining of Coal

The mining of coal is easy or difficult, according to the position, thickness, and general direction of the coal bed, or «vein.» The veins vary in thickness from a few inches to seventeen feet, in the anthracite, and reach a thickness of thirty feet in the bituminous measures. Owing to the labor involved in clearing away the rock, veins less than three feet in thickness are not often worked. In case the coal vein crops out on the side of a hill or mountain, the first step in mining is to clear away the soil and rock until the vein is laid bare. The coal is then taken out by cutting a tunnel or slope that follows the vein into the mountain. From the slope, chambers are cut in upon the sides, pillars of the coal being left in position to hold up the rocks above and to avoid the dangers of a cave-in. As coal is taken from the vein, it is carted to the opening of the slope and there prepared for market.

In most instances, however, it is found necessary to sink a shaft or well, from the surface to the coal vein below. Such a shaft may be only a few feet deep, or it may extend downward more than a thousand feet. The shaft or well is constructed with great care, for after the coal vein is reached, it remains to form a passage way from the mine, and through it the coal is hoisted to the surface. One of these shafts of a mine near Pottsville, Pa., is 1,700 feet deep, and it required four years to sink it. This shaft is 16 by 11 feet, inside the timbers with which it is lined, and is built in two compartments—one for hoisting coal and one for carrying up and down the miners and the materials for use in the mine.

When the shaft is completed, slopes are usually cut, in four or more directions from it, and the mining operations are carried on much in the same way as described. Generally a large engine is

located in a chamber near the lower end of the shaft, to furnish power for pumping and for introducing air into the mine. Such is the value of the coal that whenever it is found practicable timber is used to shore up the overlying rock, and all the coal is taken out. The miners cut out the coal in blocks or chunks as large as can be handled. These after being taken to the surface, are crushed and the fragments are sifted and sorted into grades at the mouth of the mine.

Everyone is familiar with the picture of the toil-stained miner, with a little lamp in his greasy cap, to give him light in the dark chambers of the mine. It is popularly supposed, that with only a pick, shovel, and crowbar, to assist him, he goes down into the mine and digs out his daily allowance of fuel. But in many mines where the conditions are favorable, machinery long ago took the place of the miner's pick, and in most mines to-day he is the operator of a drill, uses dynamite to break out the coal, and other machinery to load it on cars that take it to the surface.

The Pottsville shaft was cut through more than 1,500 feet of solid rock with diamond drills and dynamite. The coal is mined entirely by machinery, from the cutting drills in the mine to the endless chain appliances that prepare the product for the market at the mouth of the shaft.

The machinery now used for cutting out the coal, as it lies in the vein, is usually operated by compressed air. The cutting part consists of a huge circular saw capable of cutting fifty-six inches into a vertical wall of coal. The machine runs on rails and saws a « rib » as long as may be desired at the bottom of the wall. Then another is cut parallel with it at the top of the wall. The section is cut crosswise at intervals of about three feet. The blocks thus separated on three sides are loosened by drills on the back side, and are finally pried out from their beds, one at a time. Each block thus detached weighs about three tons and is sawed into sections before being transported to the surface.

Coal splits easily along the line of its strata, like marble or sandstone. Besides, there is a general tendency toward cleavage into square blocks, a fact that is taken into account in mining coal in large quantities. Sometimes the cohesion among the particles is so weak that the coal breaks into small particles before it can be moved. But, in most cases, the coal is brought out of the mine in chunks or blocks too large for shipment. When that is the case, machinery is used for crushing the coal and for separating it into the several marketable grades. The crushing is done by specially arranged rollers, between which the coal passes.

After passing between the rollers, it falls upon perforated screens over the chutes that convey it to the cars below. The screen upon which the coal falls is small and only the smallest fragment of coal can pass through. The coal which does not pass through is carried out to another screen whose meshes are large enough to permit the passage of the fragments of a larger size. From this screen the coal is carried on to another, with larger meshes, and then to another, with still larger meshes, and so on until the fragments of coal have been separated into as many grades as are desired. In some mines it is necessary also to wash the coal, and this is accomplished by passing it through water before it is emptied upon screens.

Through the use of machinery, where the coal veins are thick enough for the introduction of modern methods, the work of the miner has been considerably simplified. In some mines, where the veins are only a few feet thick, less expensive machinery is used, such as simple drills for loosening the blocks of coal. In some mines the pick is still used as the only available way of taking out the coal.

In coal mines two gases tend to accumulate in large quantities. These are carbonic acid gas, which is called by the miners "choke damp," and menthane or marsh gas, which is known as "fire damp."

Both of these gases were in former years sources of great danger to the miners. The carbonic acid gas, being odorless and colorless, could not be easily detected, and miners were frequently suffocated by it. The danger from the marsh gas was due to the ease with which it took fire and burned, producing violent explosions where much of it was mixed with the air. It was to prevent explosions of fire damp that the miner's safety lamp was invented. These gases are less feared now than they used to be for the reason that in large mines the air is now constantly being changed by means of ventilating machinery and large accumulations of either gas very seldom form.

Stratified Rocks

When large rock masses are studied the broad classification into Stratified and Unstratified or Massive Rocks is the most convenient. Over nine-tenths of the earth's crust near the surface is made up of stratified rocks. By stratification is meant the deposition of sedimentary matter in layers by the sorting power of water. The faces of cliffs, railroad cuttings, and mine-excavations afford good opportunity to study the mode of stratification, and the order in which the several layers have been laid down. Stratified rocks often present peculiar surface markings. Ripple marks are those produced by the wind and the rippling movement of shallow water, such as may often be seen

in the mud along the shore. Wave marks are larger than ripple marks and indicate that the formation was laid down near the shore. Rill marks are produced by the water trickling down the beach after the waves or the rain. Sun cracks occur in mud exposed to the action of the sun. These cracks are often filled up with other matter and casts are formed. Rain prints are formed by the drops of rain falling upon a soft surface. If the next incoming tide is gentle they are preserved; but they are obliterated by a storm. Tracks of animals which have passed over a soft surface are often preserved. These may be those of worms or of shell-fish and other marine forms, wading birds or of land animals. Sometimes stratified rocks are formed horizontally and remain so undisturbed, but very often some disturbing force disarranges them and they then occur in a folded or tilted manner. When tilted the degree of displacement is measured by the angle which the strata make with the horizon and this is called the dip. When a straight or horizontal line is supposed to intersect the strata, the plane of intersection is called the strike. The line of the surface of a tilted or folded strata seen on the surface of the earth is called the outcrop. The strata are sometimes of such a brittle nature that instead of accomodating themselves to the pressure or distorting force by folding, they break and are dislocated. If a crack occurs without dislocation a simple fissure is formed; but if the line of level is disarranged a fault is produced. When fissures in rocks are filled up by a later deposition of mineral, veins are formed. If these veins are filled by rich metal ore, they are then called metalliferous veins. The matter with which the veins are filled and in which the ores are imbedded is called the gangue. The gangue most frequently found in veins is either quartz, calcite, barite, or fluor-spar. If the ore of the metal is pure it is called native ore, but it is most frequently in chemical combination with other elements and occurs as sulphides, chlorides, oxides, or carbonates. It is difficult to judge of the value of a mineral vein found upon the surface, on account of the changes which weathering have produced. Therefore it is necessary to sink a shaft to get a proper idea of it. Unstratified or massive rocks are those which have been originally in a molten state far below the surface, and have been forced upward toward the surface, often protruding between stratified forms. They are either volcanic or eruptive. Volcanic rocks are most frequently lava flows or fragmental ejections, and in the case of extinct volcanoes are often so worn and weathered as to be difficult to recognize. When plutonic rocks show above the surface of the earth, that is most frequently due to the fact that the rocks which originally covered them have been eroded or worn away, rather than

that these rocks have been forced to the surface. When eruptive rocks are forced upward through a fissure the formation is called a dike and are sometimes exposed by erosion so as to form a thin facing upon a cliff. Eruptive dikes are usually composed of quartz, porphyry, basalt, or diabase. Sometimes the eruptive rocks appear in veins.

Metamorphic rocks are those which have undergone a most pronounced change by some agency other than mere disintegration. Limestone may be subjected to great heat which changes it into marble. Bituminous coal may by the same force be changed into coke, or anthracite. Mineral matter may be forced into rocks by cementation or injection. The original properties of rocks may be changed by compression. Moisture in the form of water heated under pressure to a higher degree than the ordinary boiling point may vigorously attack refractory substances not otherwise soluble.

Historical Geology

This is a study of the history of the life and formation of the earth. It is studied mainly from the rocks and the remains which they contain. The rocks tell whether or not they were formed by water. Those that were formed along shore are easily distinguishable from those formed in deep water. They also record movements which have taken place and tell something of the dynamic forces at work. The remains of organic life which they include form the science of Paleontology; and this study of fossils and their occurrence in rocks is most helpful in determining the age of the formation and in establishing a chronology, which may be relative, if not absolute. The bony skeletons of the vertebrates are often well preserved. The shells of lobsters, crabs, and trilobites; of mollusks, sea-urchins, starfishes, and corals occur in countless numbers in some of the older rocks. Very fine specimens of extinct animals are frequently found. In 1904 a bony skeleton of the extinct Ichthyosaurus was found in South America. This fact is of great geological importance as it is the first perfect specimen of the kind to be found in the New World. Fossil remains of vegetable matter are also very abundant. One of the difficulties of the study of Geology is the fact that the later formations overlie the earlier. And those that come first in the study of the history of the earth are usually the most difficult to find. Yet by distortion very often the older rocks lie above the younger. The most generally accepted classification of the eras and periods of geological formation is that which divides them into Cenozoic, Mesozoic, Paleozoic, Eozoic, and Azoic. The order here given is from the

newest rocks to the oldest. The termination -zoic in these words is from the Greek word meaning life. Cenozoic means the period of new or modern life. Mesozoic is the mediæval period of life. Paleozoic is the time of ancient life. Eozoic is that of the earliest life. Azoic is that period when no forms of life could exist upon the earth. The Azoic, or Archæan, as it is often called, is the earliest or prehistoric period in the earth's history. It is the most obscure, and the most difficult of the entire range of geological study. The rocks usually classed as belonging to this period include the crystalline and massive rocks such as granite, gneiss, schist, quartz, hornblende, mica, orthoclase. All are twisted, distorted, and bear evidence of the tremendous dynamic agencies to which they were subjected. They are of great thickness, and form the foundation or basis of the earth's structure. There were no sedimentary rocks such as sandstone, conglomerate, or limestone, in this period. The Archæan rocks are very widely distributed over the northern part of North America. This is probably the most extensive area of this formation. Smaller areas are found from Vermont to Georgia; in the Rocky Mountains; small bands from Mexico to Alaska; Missouri, Texas, New Mexico, and Arizona present small areas. In Europe they are to be seen in the Highlands of Scotland, in Ireland, in the Scandinavian peninsula. France, Germany, Bohemia, the Alps, the Pyrenees, and the Balkans present small areas. The Himalayas, the Altai, and other ranges of Asia, most of the Central plateau of Africa, small areas of Australia, the highlands of Brazil, and the Andes present more or less extensive areas. It is generally supposed that they are nearly all of igneous origin; that they were condensed from the molten state of the earth; and that they have been more or less modified by metamorphism. No fossils are formed in them, and they have been exposed by denudation.

The Eozoic period is often called the Algonkian. It is largely composed of sedimentary rocks formed at a later period than the Archæan. They, too, are much changed by metamorphic forces. Those found north of Lake Huron are called Huronian and consist mainly of quartzites, slates, cherts, and limestones. Another large area is found near Lake Superior. Others occur in many parts of Canada and the United States. The fossil remains found in the Eozoic rocks are very scanty and do not tell much about the life upon the earth at that time. This era is rich in minerals and includes the iron mines of New York, New Jersey, Michigan, Missouri; the tin deposits of South Dakota and Cornwall; the copper mines of Michigan; building stones, gold, platinum, mica, graphite, and apatite.

The Paleozoic period is much richer and more interesting on account of the great number of fossil remains which it presents. It

shows great masses of limestone, sandstones, and shales, some metamorphic and volcanic remains. Geologists consider that the Paleozoic period was of long duration, extending over millions or tens of millions of years. During the earlier part of this period the life was entirely marine. There were no land animals, no grass, trees, or vegetation, or insects. There were no fish, but the characteristic animal was the trilobite. Toward the close of the period, forests, reptiles, amphibians, and low forms of fish appeared, but no modern trees or flowers. This was an age of such long duration, and of such marked evolution, that it has been found necessary to subdivide it into periods. The earliest is the Cambrian. It is so named from Cambria, the old name for Wales, in England, and it was first studied between 1830 and 1860.

The American representatives of the Cambrian are classified into (1) Lower Cambrian, or Georgian Epoch; (2) Middle Cambrian, or Acadian Epoch; and (3) Upper Cambrian, or Potsdam Epoch. The Georgian Epoch takes its name from Georgia, Vermont, where representative rocks are found. The Acadian is named from the old name of Nova Scotia and New Brunswick in Canada, from some representatives found near St. John, New Brunswick. The Potsdam took its name from the locality in northern New York. The rocks are shales, sandstones, conglomerates, and a few limestones. The Potsdam rocks are found at the base of the Adirondacks, and show red sandstones and shales. The fact that limestones occur at all in the Cambrian rocks show that life was abundant; for limestone is formed from calcareous deposits of shells. Some Protozoa, sponges and corals, appear; Echinoderms, one- and two-shelled mollusks; the Lingulella and other Brachiopods are abundant. The Trilobite is the most frequently occurring of marine species. It is a crustacean, with an outside skeleton, body rings and appendages. The body is divided into three lobes or parts, and vary in length from one inch to two feet. Over 50 species are found in a fossil state in the Lower Cambrian rocks. Following the Cambrian period is the lower Silurian or Ordovician. It is further divided into (1) Calciferous Epoch; (2) Chazy Epoch; (3) Trenton Epoch; (4) Utica Epoch; (5) Hudson Epoch. These names were given because the period was first worked out in the State of New York about 1840. The rocks of the Calciferous Epoch are sandstones containing much lime. The Chazy Epoch is named from a small village, and the rocks are richer in lime. They are found in the St. Lawrence region and in northeastern New York. The Trenton Epoch was the most important of the Lower Silurian. Those animals which appeared in small numbers in the Cambrian rocks are seen in abundance in the Lower Silurian, corals,

crinoids, and mollusks especially. The crinoids are lily-like animals known as cystids. Higher forms of Brachiopods and Mollusks occur. The Trilobites become more complex and varied in form. The earliest known insect appears in the Lower Silurian of Europe, but not in America. Fishes were found in 1892 in the Trenton rocks near Cañon City in Colorado. The rocks of the Lower Silurian furnish building stones, and marble. In Illinois, the Galena limestone gives lead ore. In Ohio and Indiana, Trenton limestone supplies natural gas. In Kentucky, it gives the rich soil of the blue-grass region. The third division of the Paleozoic period is the Upper Silurian. It is subdivided into (1) Medina Epoch; (2) Clinton Epoch; (3) Niagara Epoch; (4) Salina Epoch; (5) Waterlime and Tentaculite Epoch. The rocks are sandstones, shales, a few limestones. From the limestones of the later epochs, hydraulic cement is made. Land plants begin to appear in the Upper Silurian. The Spirifers, or spiral-shelled forms, come in the Clinton Epoch. The most important economic product of the Upper Silurian rocks is common salt, especially in the salt regions of New York state. The Devonian is the fourth division of the Paleozoic era, and is subdivided into (1) Hilderberg Epoch; (2) Oriskany Epoch; (3) Corniferous or Onondaga Epoch; (4) Hamilton Epoch; (5) Chemung Epoch. The rocks are limestones, with numerous fossils; sandstones; shales, and shaly sandstones. Sponges are found in abundance in the Corniferous Epoch, and are mixed in the nodules of flint among the rocks of that time. Corals, true crinoids, star-fishes, Brachiopods, Spirifers, Mollusks rise in abundance both of species and individuals. Crustacea and fishes are extremely numerous. Land plants become abundant. The Carboniferous Period is the fifth division of the Paleozoic Era. It takes its name from the coal deposits formed at that time. It is subdivided into Early, Middle, and Late Carboniferous. The coal measures of the east rest upon a series of coarse Pottsville conglomerates. Above these are shales, sandstones, limestones, and coal beds. The plants of the period are well preserved in fossil form in the coal beds. There were in all about 2,000 species of plants in this age. They included ferns, tree ferns, lycopods, the Lepidodendron or scale-tree which was over 50 feet high and whose trunk measures from 2 to 4 feet in diameter, the Equiseta, or horse tails, which instead of being a few inches high as now often rose to a height of from 20 to 40 feet. Animal life abounded, spiders, scorpions, flies, locusts, and cockroaches are seen.

The Mesozoic era, or the age of Reptiles as it is often called, represents the transition from the older forms of life to the newer. The reptiles were the most marked characteristic of the age. They were

of enormous size and lived both on land and in water. The era is divided into the Triassic and Jurassic. The Triassic is named from a three-fold grouping in Germany; and the Jurassic from the Jura Mountains. The rocks are mainly sandstones, conglomerate, shale, and some limestone. The rocks appear to be of a fresh-water formation as they contain no marine fossils. Reptilian tracks are common in the sandstones as are also ripple marks, mud cracks, and rain-drops. The palisades of the Hudson are formed by the outcrop of great lava beds of this period. Triassic rocks occur in the Black Hills, the Front Range of Colorado, the slabs and pillows of the Garden of the Gods, and the Vermilion Cliffs of Colorado. Jurassic rocks are also found in these regions and it was during this period that the Sierra Nevada Mountains were elevated. The forests changed considerably in appearance. The larger Lepidodendrons and the Sigillarius dwindle in size, the Ferns and Horsetails and Gymnosperms, especially the Conifers and Cycads, are dominant. No true flowering plant occurs so far as is known. The forms of life are confined to the fresh water and the land series. The Amphibians were of prodigious size. The Ichthysaurus or fish lizard was from 30 to 40 feet long with a long powerful pair of jaws and sharp teeth. Its eyes were disproportionately large and its limbs and tail were finned. There were from 30 to 50 species of this monster in the waters. The Pleisiosaurus occurs in 50 fossilized species. The form was slender, tail short, neck long, and its fins large; it measured from 25 to 30 feet. It was also a water animal. The Dinosaur was the terrible lizard or reptile which lived on land. It was both graminivorous and carnivorous. The Brontosaurus was 60 feet long. The Atlantosaurus found in Colorado was from 70 to 80 feet. Its thigh-bone was 6 feet long and a single vertibra was 2 feet in diameter. The Stegosaurus had a huge row of bony plate down the back. The Plerosaurus was a fearful combination of reptile and bird, without feathers.

The « brown stone » building stone is Triassic and the chief quarries have been for years in Connecticut and Massachusetts. The coal beds of Virginia and North Carolina are Triassic. The quartz gold fields of Sierra Nevada are Jurassic as are the auriferous slates of California.

The Cretaceous period of the Mesozoic era takes its name from the large chalk deposits of the time. The western portion of America was largely submerged at this time, the Rocky Mountains showing as a mere island. It is the submergence that explains the finding of cretaceous beds of fossils of marine animals at a present height of 10,000 feet. The chief progress was in the life of the period. The forests began to look like those of the present day. Elms, Maples,

Beeches, Willows, and Birch were common. The period is rich in the higher forms of marine animals. The reptiles still ruled. The Mosasaur is a new form of reptile. Remains of it have been found in Kansas and other parts of America. It was very slender and more like the lizards and snakes but it was 75 feet long. Lizards and crocodiles were common; and some of the flying reptiles had a width of 20 feet of outspread wings. The coal of the Laramie coal fields of Kansas, New Mexico, Colorado, Wyoming, and Dakota are cretaceous. The only anthracite coal of that period, so far as is known, is near Elk Mountain west of the divide.

The Cenozoic era is the last of the geological eras of the world. It is the era of new or modern life. It is the age of mammals, for the reptiles disappear. It is the age when the great mountains of the Old World appeared — the Himalayas, the Alps, and the Pyrenees. The two periods are the Tertiary and Quaternary. During the Tertiary period the western part of America, which had been submerged during the Cretaceous Epoch, reappeared. Its upward motion was slow and gradual. Volcanic action was remarkable and the great lava formations of the West occurred then. The Tertiary period is subdivided into the Eocene, Miocene, and Pliocene Epochs. This division is based upon the percentage of fossils in invertebrate animals now living.

The Eocene contains 5 per cent. or less; the Miocene, 50 per cent., the Pliocene, over 50 per cent. The reptiles disappeared either from instability or constitution or unsuitableness of environment. Among the mammals were the Zengtodon, a form of whale with odd shaped teeth; the Mastodon with nipple-shaped tooth; the Dinothenium with a horn like that of a hippopotamus projecting downward from the lower jaw. The pig, the early oxen, camels, and monkeys were first seen. The evolution of the horse through these times is most interesting. In the early Eocene age he was the Eohippus about the size of a fox with three toes on the hind foot and four and a rudimentary one on the fore foot. As the Orohippus of the later Eocene he is larger and the rudimentary toe has disappeared. In the Lower Miocene he is the Mesohippus and in the Miocene the Miohippus where the fourth toe becomes rudimentary. In the Lower Pliocene and in the Pliocene he is the Protohippus, and the Pliohippus when the side toes shorten; and in the Quaternary he is the Equus with only one hoof.

The Quaternary period extends from the Tertiary to the present time. It is divided into the Glacial and the Post-Glacial Epochs. The general name of drift is given to all matter removed by the action of the glaciers during the Glacial Epoch. Among this matter is bowlder

clay or till. It is a clayey, loamy mass of unstratified material usually containing a number of stones. The till is often blue, tough, and compact, showing the pressure and weight of the glacier. Other remains are the huge bowlders which have certainly been transported long distances. Professor Louis Agassiz in 1840, from a study of glaciers in the Alps, showed conclusively that the drift was of glacier origin. During the Glacial period the ice extended over the greater part of eastern Canada and the northeastern United States. Another sheet extended over the middle of the country westward to the Rockies in Canada. They were found as far south as Colorado. All of New England was under ice as far south as Long Island and Staten Island and only a small portion of New York state was uncovered. Thence the southern boundary passed to Cincinnati, southern Indiana and Illinois, into Kansas, Nebraska, Dakotas, and Montana. The ice was often one mile thick. The ice slowly melted and receded causing floods as it disappeared. The most remarkable of the Tertiary mammals in America were the elephants. Remains indicate that they roamed over all of North America. The Megatherium of South America was an enormous beast shaped something like a bear but often over 20 feet long. One interesting European specimen is the Irish Elk whose remains have been found in peat-bogs in which he sank. The antlers of one specimen has a spread of over 12 feet. Some mammoths have been embedded in masses of ice in Siberia and thus preserved.

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